A WEB-BASED GROUP DECISION SUPPORT SYSTEM FOR SUPPLIER EVALUATION AND SELECTION

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Onur Eren Sürgit

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Thesis Abstract

Onur Eren Sürgit, "A web-based group decision support system for supplier evaluation and selection"

Supplier selection is one of the vital processes which have an impact on the competitiveness of firms by affecting their costs, the quality of goods and services produced, and customer satisfaction. Suppliers' evaluation is a multi criteria decision problem associated with several perspectives such as cost, quality, logistics, production, finance and sales. This necessitates the involvement of different parties within a firm and requires a group of decision makers to work collaboratively to come up with an acceptable solution. Additionally, the evaluations should be repeated on a periodical basis by keeping track of the past performances and the decision process should be as short as possible to be responsive in a competitive environment. In this study, a web-based group decision support system (GDSS) environment is developed to solve the supplier selection problem by using an Analytic Hierarchy Process model. The GDSS provides a flexible and dynamic environment which enables the participation of several parties with the use of advanced web technologies in order to cope with the complexities of the supplier selection problem.

Tez Özeti

Onur Eren Sürgit, “Tedarikçi değerlendirmesi ve seçimi için web tabanlı bir grup karar destek sistemi”

Tedarikçi seçimi, üretilen ürün ve hizmetlerin kalitesini, maliyetlerini ve dolayısıyla da müşteri memnuniyetini etkileyerek, firmaların rekabet gücünü değiştirebilen hayati süreçlerden birisidir. Tedarikçilerin değerlendirilmesi maliyet, kalite, lojistik, üretim, finans, satış gibi farklı bakış açılarıyla yaklaşılması gereken çok ölçütlü bir karar problemidir ve firmanın içindeki farklı fonksiyonel birimlerdeki karar vericilerin birlikte çalışmasını gerektirir. Ayrıca, bu değerlendirmelerin belirli aralıklarla tekrarlanması ve performansın izlenmesi büyük önem taşır. Bu nedenle geçmiş tedarikçi performanslarının ve değerlendirme süreçlerinin kayıt altında tutulması ve karar verme sürecinin mümkün olduğunca kısa olması rekabetçi ortamda hızlı hareket edebilmek için ön şartlardır. Bu çalışmada, tedarikçi değerlendirme problemini çözebilmek için Analitik Hiyerarşi Prosesi’nden (AHP) faydalanılarak web tabanlı bir grup karar destek sistemi (GKDS) geliştirilmiştir. GKDS, tedarikçi değerlendirme probleminin tüm karmaşıklığına karşın, farklı birimlerdeki katılımcılar için gelişmiş web teknolojilerinin kullanıldığı, esnek ve dinamik bir değerlendirme ortamı sağlar.

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CONTENTS

TABLES

FIGURES

FORMULAS

ABBREVIATIONS

GDSS: Group Decision Support Systems
AHP: Analytical Hierarchy Process
MCDM: Multi-Criteria Decision Making
GDM: Group Decision Making
RDMS: Relational Database Management System
DAL: Data Access Layer
GUI: Graphical User Interface
DEA: Data Envelopment Analysis
CBR: Case-Based Reasoning
CSCW: Computer-Supported Cooperative Work
CMCS: Computer-Mediated Communication Systems
DM: Decision Maker

CHAPTER 1:

INTRODUCTION

Supplier evaluation is the process by which suppliers are reviewed, assessed, and chosen to become part of the company's supply chain. In the current business environment, global competition among companies has increased and customer demands have diversified which resulted in increased costs and decreased profits. In order to achieve competitive advantage it is important for firms to spend the minimum time and effort to find the best, or most appropriate, supplier. Supplier selection activities constitute a huge part of the product realization process (Gencer and Gürpınar, 2006). They include all activities from purchasing of material till the end delivering the product. Supplier selection decisions play a vital role in production decisions for many firms. It has been stressed as one of the most crucial issues in the process of product design. It commits resources while simultaneously impacting activities such as inventory management, production planning and control, cash flow requirements, and product quality (Demirtaş and Üstün, 2008).

Companies generally need to work with different suppliers to continue their activities. As the product life cycle has shortened, the need for closer relations with suppliers gets more significant for innovative and rapid product development. Moreover, global competition compels organizations to integrate their business processes with suppliers and forces them to develop new strategies for purchasing and manufacturing. Selecting right suppliers is a vital component of these strategies.

All firms, producing goods or delivering services need customers to buy their products. Today, supplier selection process is much more customer satisfaction oriented (Hou et al., 2004). Firms shift their way of doing business from product-driven to demand driven and focus on quickly and precisely responding to customer. This forces business enterprises to actively invest in supply chain management, and to establish a sounder strategic alliance against competitors (Chou and Chang, 2007).

Managing the purchasing task in the supply chain has been a challenge in the last decade for many corporations. The need to gain a global competitive edge on the supply side has increased substantially. Particularly for companies who spend a high percentage of their sales revenue on parts and material supplies, and whose material costs represent a larger portion of total costs, savings from supplies are of particular importance (Saen, 2006).

Purchasing decisions have major impact on organizations. Systematic and error-proof methods should be followed up while making those decisions. There are two main reasons for this. First in many companies, the cost of the purchased goods and services accounts for more than 60% of the cost of goods sold. Second, over 50% of all quality defects can be traced back to purchase material (Gencer & Gürpınar, 2006).

In most industries the cost of raw materials and component parts constitutes the main cost of a product, such that in some cases it can account for up to 70% (Ghodsypour and O'Brien, 1998). The cost of components and parts purchased from external sources by large automotive manufacturers may total more than 50% of revenues (Weber & Current, 1991). In such circumstances the purchasing department can play a key role in cost reduction, and supplier selection is one of the important functions of purchasing management. That is why many experts believe that the supplier selection is the most important activity of a purchasing department (Saen, 2006).

The success of a supply chain is highly dependent on selection of good suppliers. Simply looking for vendors offering the lowest prices is not considered as "efficient sourcing" strategy any more. Performance of suppliers which has been evaluated on multiple criteria become a key element in a company's quality success or failure and clearly influences the quick response ability of the company. In order to attain the goals of low cost, consistent high quality, flexibility and quick response, the process of reengineering the company activities must also include the supplier selection process (Barbarosoğlu & Yazgaç, 1997).

Supplier selection process is not a onetime evaluation based on multiple criteria. Actually, the performance of suppliers should be continually traced in fixed time intervals to achieve stability of the system goals. Furthermore the evaluation of suppliers requires the involvement of multiple departments like production, quality, logistics, sales, marketing, and finance. This issue is more significant in global companies where functional units are geographically dispersed, since the long distances increase the complexity of the evaluation process. These requirements can be handled by the use of group decision support system (GDSS) which enables continuous, fast and timely tracing of supplier performance by the inclusion of multiple parties in the evaluation process.

Evaluation of suppliers on a multi criteria basis requires the use of multi criteria decision modeling methodologies. Along with several other approaches, analytical hierarchy process (AHP) modeling constitutes an integral proportion in all studies. In this study, a web-based decision support environment has been developed to solve supplier selection problem by AHP modeling. Supplier Selection and Evaluation System (SSES) is designed to cope up with the complexities associated with the interdisciplinary nature of the problem, unanticipated emergence, similarity and repeatability. SSES facilitates communication among team members, regardless of the geographical limitations and group decision pitfalls such as fear of expressing ideas or dominance of some participants. The system also aims to provide a group satisfactory solution which is one that is most acceptable by the group of individuals as a whole. It is, therefore, designed to increase the level of overall satisfaction for the final decision across the group. Figure 1 depicts the areas on which this study is focused. SSES is placed in the intersection area where GDSS's as a subset of decision making environments meet with web technologies for the solution of supplier selection problem.

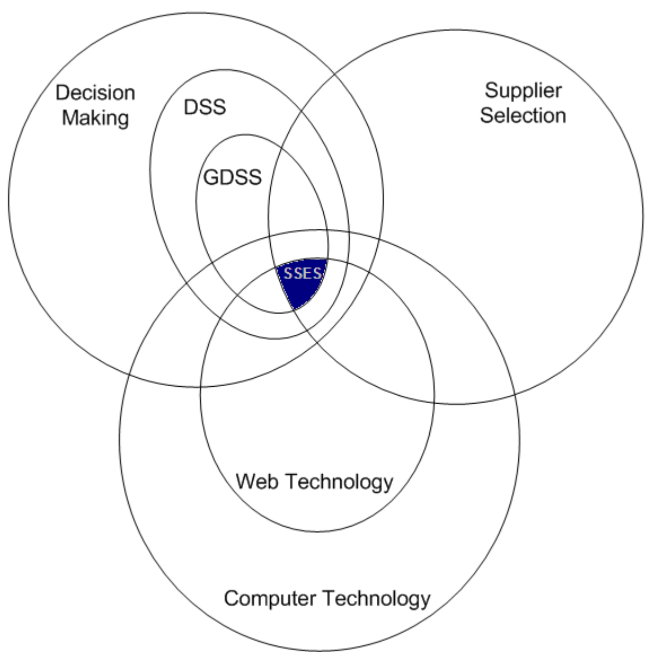


Figure 1. Areas related to SSES
(Adapted from Tiwari M. K., Banerjee R. (2001))

The organization of the study is as follows: In Chapter 2, background information on group decision support systems is given. In Chapter 3, a comprehensive literature review for supplier selection and evaluation methodologies, criteria used for supplier selection and group decision support systems are provided. In Chapter 4, the development of AHP model is explained in detail in terms of supplier selection criteria and AHP hierarchy. Chapter 5 deals with the development of DSS environment including technical design and GUI concerns. Implementation and evaluation of DSS environment is provided in Chapter 6 which consists of the details of pilot study and features of the system. The study concludes with a summary and future works that might be conducted to enhance the system.

CHAPTER 2:

BACKGROUND

Group Decision Support Systems (GDSS)

Decision problems are heavily affected by rapidly changing market environment, high competition and thus they are complex. Main properties which are shaped by these factors and cause the complexity of such decisions are its interdisciplinary nature, unanticipated emergence, similarity and repeatability.

In organizations, many decisions and the processes involved in making them are performed at a group level rather than individually (Lu et al., 2005). Decision problems are often interdisciplinary problems associated with several perspectives or domains such as cost, production, finance, sales etc. That means, in most cases, a group made up of experts and authorized people from various domains will be needed to make collaborative decisions on problems. At the same time, group members may be distributed geographically. Interdisciplinary nature of such decisions brings several difficulties. Firstly it is sometimes difficult to achieve consensus among group members, or for all members of a group to meet (Dyer & Forman, 1992). Secondly, some members tend to dominate the group. Therefore it is necessary to avoid dominance of some members among other decision makers and give every member an equal chance to express their own ideas.

Another factor for the complexity of managerial decision problems is the need for rapid decision making. The speed of decision making is critical in responding quickly and easily to the competitive and rapidly changing markets. Furthermore, general managerial decision problems are similar to an extent thus inheritance of prior know-how and experiences are also critical for keeping rationality in decision making. Keeping track of past decision problem processes helps firms to improve the accurateness of its decision making and reduce the number of mistakes made.

Most of the decision problems are not the ones which are solved once and not faced again. Namely, decision making processes are being repeated periodically depending on the policies of organizations. For instance, firms conduct supplier selection and evaluation at least two to three times a year. It means steps for evaluating suppliers are repeated every four to six months.

One possible way to meet the above requirements is to apply group decision support system (GDSS). As a branch of information technology, GDSS has the potential to promote active participation, encourage interaction and facilitate decision analysis in operational management. Generally, it supports groups of people and engages them in common tasks through the interface of a shared environment (Huang & Wang, 2005).

Tam et al. (2001) propose that group decision-making process can be improved by a systematic and logical approach to assess priorities based on the inputs of several people from different functional areas within the company. GDSS facilitates communication among team members, regardless of the geographical limitations and group decision pitfalls such as fear of expressing ideas or dominance of some participants.

A group decision making process is to find a group satisfactory solution which is one that is most acceptable by the group of individuals as a whole. It, therefore, is very important to determine what makes group decision-making effective and to increase the level of overall satisfaction for the final decision across the group.

Due to the importance and complexity of the group decision-making process, decision-making models are needed to establish a systematic means of supporting effective and efficient group decision-making. Decision support systems (DSS) have been applied as a support tool for solving GDM problems, referred to group decision support systems (GDSS) since computation of GDM methods are complex (Lu et al., 2005).

First studies on GDSS started in the 1980s. DeSanctis et al. (1985), define GDSS as an interactive, computer-based system that facilitates the solution of unstructured problems by a set of decision makers working together as a group. In 1987, they focused on the effectiveness of GDSS on communication and enhanced their definition; they proposed that a GDSS aims to improve the process of group decision making by removing common communication barriers, providing techniques for structuring decision analysis, and systematically directing pattern, timing, or content of discussion. Later Turban (1988) described GDSS as a set of software, hardware, language components and procedures that support a group of people engaged in a decision-related meeting. The use of group decision support systems (GDSSs) provides technological efficiencies and interaction advantages that can overcome some of the difficulties frequently encountered among large teams (Dennis 1991). In early 2000's Basoglu et al., (2001) propose that extending decision systems toward GDSS needs extra effort because group systems are social systems which affects and affected by the environment and they also covers computer-based information systems. Groups systems are part of highly social systems, which envelops computer-based information systems. Wanga and Chien (2003) define

GDSS as an interactive computer-based system that facilitates the solving of unstructured or semi-structured problems by a group of decision-makers. GDSS is an interactive computer-based information system that combines the capabilities of communication technologies, database technologies, computer technologies, and decision technologies to support the identification, analysis, formulation, evaluation, and solution of semi-structured or unstructured problems by a group in a user-friendly computing environment (Er and Ng, 1995; Fan et al., 2008).

Initial studies on GDSS reveal the general definition and aim of group support in decision support systems. Later on, researches focus on the ways to make those systems more effective in terms of communication and content of group discussion. More emphasis on communication channels and interaction opportunities is placed at 90's. Most recent and comprehensive definitions of GDSS deal with the computer support, communication technologies and decision technologies together. Recent studies also suggest some architecture on technical design and modeling considerations for making GDSSs more user-friendly, efficient and compact. GDSSs begin to shift to a web-based form by the increasing developments in web technologies. Turban and Aronson (2001), divide communication into four cells each of which represent computerized support technologies. The four cells are organized along the dimension of time and place. Web-based GDSSs is placed in all four cells (same time / same place, same time / different place, different time / same place, different time / different place).

Most complex decisions are made by groups in organizations. Group support in decision making is a critical aspect of this century's decision support systems. The increase in organizational decision making complexity increases the need for group work.

Supporting group work where team members may be in different locations and working at different times emphasize important aspects of communications, computer technologies, and work methodologies (Turban and Aronson, 2001).

The Technology Aspect of GDSS

Recent studies of group decision support systems use mainly traditional, face-to-face, facilitated GDSS. These types of systems generally use client based technologies running on local area networks which disable applying its results to distributed teams. There are also asynchronous computer conferencing systems that support distributed teams by providing discussion forums where ideas posted from users at anytime are stored and classified in order to be read later on. These types of systems do not have explicit support for decision-making processes and often do not provide tools for alternative evaluation (Chen et al., 2003).

Within many organizations, teams use technology to support their tasks. These tasks are often performed within a context of group problem-solving processes dealing with interdepartmental issues. Here “collaboration” is defined as activities that involve people engaged in various business processes (e.g., marketing, engineering, research, and development) working together by sharing information and making decisions (Chen et al., 2007). For example, to build effective supply chain integration and customer services, it is important to involve not only employees of various departments but also suppliers and even customers in certain decision-making processes. The group activities performed by teams while working together include communicating ideas, exchanging and sharing information, coordinating activities, discussing issues, and making decisions. Collaboration technologies have evolved from various origins; therefore, people use various terms to describe these technologies, such as groupware, inter-personal computing, group decision support systems (GDSS), computer-supported cooperative work (CSCW), computer-mediated communication systems (CMCS), and team technologies.

Traditionally, DSS, including GDSS, has to be installed in a specified location, such as a decision room. With the development of information and communication technologies, the web is acting as a mechanism for the support of decision-making in organizations, particularly geographically distributed organizations. GDSS can therefore be implemented as a kind of web-based service in global environment. By the advances of web technologies, which allow users fast and inexpensive access to an unprecedented amount of information provided by websites, digital libraries and other data sources, web-based DSS have been applied in a widespread decision activities with its unified graphical user interface (Lu et al., 2005).

CHAPTER 3:

LITERATURE SURVEY

In this section a review of studies in the literature has been proposed for supplier evaluation and selection methodologies, criteria used for supplier selection and decision support systems.

Supplier Evaluation and Selection Methodologies

Supplier selection is the process by which suppliers are reviewed, evaluated (compared), and selected to become part of the company's supply chain. The supplier selection process has undergone significant changes during the past twenty years. These include increased quality guidelines, improved computer communications, and increased technical capabilities (Weber et al., 2001). The objective of supplier selection is to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost. Selection is a broad comparison of suppliers using a common set of criteria and measures. However, the level of detail used for examining potential suppliers may vary depending on a firm's needs. The overall goal of selection is to identify high potential suppliers (Kahraman et al., 2003).

Supplier selection is a complex multi-person, multicriteria decision problem which includes both qualitative and quantitative criteria. Kumar et al. (2006), lists several reasons for the complexity of the supplier selection problem. These are stated as the need to evaluate vendors on more than one criterion; existence of suppliers with different performance characteristics; additional constraints related to vendors' internal policy and externally imposed system constraints of the supply chain that put restrictions on vendors' quota allocation, number of vendors to employ, minimum and maximum order quantities, use of minority vendors etc and finally, suppliers' constraints such as production capacity and minimum order quantities. In order to select the best suppliers it is necessary to make a trade off between these tangible and intangible factors some of which may conflict (Ghodsypour & O'Brien, 1998) (Tam & Tummala, 2001) (Narasimhan, 1983). The evaluation of intangible factors requires the assessment of expert judgment, and the hierarchical structure that require decomposition and synthesis of these factors (Barbarosoğlu & Yazgaç, 1997). In supplier selection problem the objectives are not equally important. Besides, in real cases, many input data are not known precisely for decision-making (Amid et al., 2006). The assumption of classical supplier selection models is based on complete homogeneity of suppliers. In spite of this assumption in many applications some suppliers do not comprehensively consume common inputs to comprehensively supply common outputs (Saen, 2007). Choice of the best alternative is a widespread problem in the activities of human beings. In general, to make a choice individuals compare the features of the available alternatives while taking into consideration a number of important aspects (criteria). According to the results of descriptive studies, the multi-criteria choice problem is a great challenge for human beings, and the more criteria the problem involves, the more difficult the problem is (Ashikhmin & Furems, 2005).

Definition, importance and level of criteria may show deviations among functional units (department) within an organization. Each functional unit put emphasis to different criteria and also has different way of measuring it. Supplier selection is a cross-functional, group decision-making (GDM) problem, frequently solved by a non-programmed decision-making process, and involving long-term commitment for a company. Depending upon the purchasing situations, criteria have varying importance and there is a need to weight criteria (Dulmin and Mininno, 2003). A decision group includes many decision-makers / experts (DMs) such as the research and development (R&D), engineering, quality assurance, and financial personnel. In reality, the importance (or reliability) of individual DMs may not be equal or uniform (Chou & Chang, 2007). Since the supplier selection process addresses different functions within the company it is a multiple criteria decision-making (MCDM) problem which is affected by several conflicting factors.

As a consequence of these facts, selection of criteria, determination of methodologies, and evaluation process has strategic importance for businesses and decision makers (Wei et al., 2001). Suppliers have varied strengths and weaknesses which require careful assessment by the purchasers before ranking can be given to them. So, every decision needs to be integrated by trading off performances of different suppliers at each supply chain stage (Liu & Hai, 2005).

Supplier selection is generally a long and exhaustive evaluation process. Organizations spend huge amount of resources such as time, money and work force in order to select the best suppliers under rapidly changing business environments. There are many sources of differences in supplier evaluation process among various industries. Criteria which are used in selection process, total number of suppliers to be evaluated and the period of each evaluation term are just some examples of those differences. Even organizations within the same industry might follow different methods and criteria in the supplier selection process.

Although the supplier evaluation and selection process show some differences among different industries, it has many steps and properties in common. According to (Sucky, 2006), evaluating and selecting a strategic vendor can be organized within a two stage process. The first stage closely follows traditional forms of vendor evaluation where, the evaluation is restricted to qualitative criteria. A review of alternative vendor evaluation techniques is given by (Talluri & Narasimhan, 2004). The effect of such qualitative screening at the first stage is that a threshold performance level is established, and any supplier below that level is not being considered for a strategic partnership. The evaluation in the second stage is focused on quantitative criteria, where the strategic vendors are selected from the reduced set (pool) of potential vendors. Overall, the proposed two stage process involves different sets of criteria and a combination of different decision models. De Boer et al. (2001) argue that there are four research subjects within the research field of supplier selection: problem definition, formulation of criteria, pre-qualification, and final selection, with the latter two being most actively pursued.

There are many different methodologies used in supplier selection such as cluster analysis, case based reasoning systems, statistical models, data envelopment analysis, analytic hierarchy process, total cost of ownership, activity based costing, artificial intelligence, mathematical programming (Gencer & Gürpınar, 2006).

In a detailed analysis of 103 studies, the most popular methodology for supplier selection is identified as AHP with 20 studies (approx. 20 %). Other methodologies used are mixed-integer programming (12 %), linear programming (10 %), mathematical programming (10 %) and DEA (8 %), etc. The summary of this analysis is shown in Table 1. Table provides a matrix table of goals for supplier selection related areas and methods to achieve these goals. Columns represent the supplier relations oriented problems such as supplier selection and evaluation, order allocation and some others like determining number of suppliers to employ, formulation sourcing strategy etc. There are many other problems related to supplier relations. Each row, however, includes a decision method which is beneficial to solving the corresponding problem in the literature. Methods which are similar in terms of input, processing of inputs and outputs are grouped into single row for the sake of simplicity of the table. Studies plotted in the table, are conducted between 1968 and 1998. Out of 103 studies 84 of them are focused on supplier evaluation and selection which is also the focus point of this thesis.

Earliest study that benefited AHP for supplier selection problem is dated to 1983. AHP found many application areas in supplier evaluation and selection processes since 1983. Based on these discussions, in the thesis study, AHP, which is one of the most popular methods in literature is selected as the methodology for the evaluation of suppliers. The criteria to be used in this evaluation are identified by a literature survey in this area are discussed in the next section.

Table 1. Supplier Selection Goal and Method Matrix

	Supplier Selection and Evaluation	Order Allocation	Determine the number of vendors to employ and Formulate sourcing strategy	Total Number Of Studies
Cost Based Model and Total Cost of Ownership (TCO)	Timmerman 1986, Monczka and Trecha 1988, Smytka and Clemens 1993, Youssef et al. 1996			4
Data Envelopment Analysis (DEA)	Weber and Ellram 1992, Weber and Desai 1996, Papagapiou 1996, Weber et al. 1998, Liu et al. 2000, Forker and Mendez 2001, Talluri et al 2006		Braglia and Petroni 2000	8
Multiple Attribute Utility Theory			Braglia and Petroni 2000	1
Combined Scoring Method	Kwong et al. 2002			1
Total Cost of Ownership (TCO)	Bhutta and Huq 2002, Degraeve 2000			2
Analytic Hierarchy Process (AHP)	Narasimhan 1983, Nydick and Hill 1992, Willis et al. 1993, Barbarosoglu and Yazgaç 1997, Ghodsypour and O'Brien 1998, Yahya et al. 1999, Masella and Rangone (2000), Sarkis and Talluri 2000, Lee et al. (2001), Muralidharan et al. (2001), Tam & Tummala (2001), Bhutta and Huq 2002, Kahraman et al. 2003, Cebi and Bayraktar 2003, Wang et al. 2004, Liu and Hai 2005, Akman & Alkan (2006) Kokangul & Susuz (2008)		Xia and Wu 2007, Ghodsypour et all 1997	20
Mixed Integer Programming	Gaballa (1974), Narasimhan and Stoynoff (1986), Turner (1988), Ghodsypour et all 2001	Gaballa (1974), Bender et al. (1985), Narasimhan and Stoynoff (1986) Liao & Rittscher (2006), Aguezzoul & Ladet (2007), Kokangul & Susuz (2008)	Dahel 2003, Ghodsypour et all 1997	12
Integrated Lexicographic Goal Programming (LGP)	Cebi and Bayraktar 2003			1
Evolutionary Fuzzy System	Ohdar and Ray 2004, Ordoobadi 2009			2

Table 1. continued

	Supplier Selection and Evaluation	Order Allocation	Determine the number of vendors to employ and Formulate sourcing strategy	Total Number Of Studies
Visual Interactive Goal programming (VIG)	Karpak et al. 2001			1
Max–Min Productivity Based Approach	Karpak et al. 2001, Talluri and Narasimhan 2003			2
Gittins Indices	Azoulay-Schwartz et al. 2004			1
Goal Programming and 0–1 integer programming	Karpak et all 1999, Hajidimitriou and Georgiou 2002, Kumar et al. 2004, Wang et al. 2004, Ip et al. 2004	Dağdeviren & Eren (2001), Pehlivan (2007)		7
Mathematical Programming and Multi-Objective Programming (MOP)	Buffa and Jackson 1983, Sharma et al. 1989, Chaudhry et al. 1993, Weber and Current 1993, Degraeve and Roodhooft 2000, Weber 2000, Hong et al. 2005	Buffa and Jackson 1983, Bender et al. 1985, Dagraeve and Roodhooft (2000)		10
Dual-Matrix Approach	Degraeve et all 2000			1
Fuzzy Multiple Attribute Decision Making (FMADM)	Chang et al. 2006			1
Case-Based Reasoning (CBR), Artificial Intelligence (AI), Neural Network (NN) and Expert System	Ng et al. 1995, Vokurka et al. 1996, Cook 1997, Albino and Garavelli 1998, Khoo et al. 1998, Kwong et al. 2002, Dulmin and Mininno 2003			7
Multiple Criteria Decision Aid (MCDA)	Dulmin and Mininno 2004			1
Linear Programming and Linear Weighting	Wind and Robinson (1968), Fearon (1973), Zenz 1981, Timmerman 1986, Soukup 1987 Monczka (1988), Pan (1989), Ghodsypour 1998	Özgen et al. (2007), Sevkli et al. (2007)		10
Statistical Approach and Cluster Analysis	Hinkle et al. 1969, Ronen and Trietsch 1988, Soukup 1987, Holt 1998			4

Table 1. continued

	Supplier Selection and Evaluation	Order Allocation	Determine the number of vendors to employ and Formulate sourcing strategy	Total Number Of Studies
Other Decision Making Frameworks	Weber 1993, Chaudry S.S. et al. 1993, Kasilingam R.G. 1996, Jayaraman et all 1999, Cakravastia et al. 2002, Humphreys et al. 2003, Chen et al. 2006			7
Total Number Of Studies	84	13	6	103

Criteria Used for Supplier Selection

Supplier selection and evaluation studies started in 1960's with Dickson (1966) who identified 23 criteria that ought to be considered by purchasing personnel in evaluating suppliers. His study shows that quality is the most important criterion followed by delivery and performance history. Later, Weber et al. (1991) review 74 articles which address vendor selection criteria in manufacturing and retailing environment and they conclude that supplier selection is a multi-criteria problem and the priority of criteria depends on the firms strategic management decisions. Several studies were made till the 1990s and over 60 criteria have been identified for supplier selection (Roa et al. 1980, and Bache et 1987). Among these the most significant ones are price, quality, availability and delivery. Similarly a comprehensive review of criteria for supplier selection conducted by Ghodsypour, S.H. and O'Brien, C. (1998) shows that the number and the weights of criteria depend on the purchasing strategies followed by the company.

Hou et al. (2004) argue that in general potential suppliers are evaluated on several criteria such as technical capability, material selection, production technology, prices, product quality, service and geographic location. Extensive research reveals that the selection of suppliers is not only a technical decision; there is an increasing requirement need to consider some factors from business perspective. As a business decision, an organization's vision, mission, priority and criteria must be taken into consideration as well. With regard to these issues, tangible criteria are inevitably considered such as pricing structure, delivery capability, product quality, and service issues. Additionally, intangible factors also needed to be taken into account. Such as affects by the external environmental changes. Fawcet et al. (1997) defined a measure of the firm's logistics performance concerning key factors such as cost, quality, delivery, flexibility and innovation. Another comprehensive study is conducted by Tam et al (2001) in the telecommunication industry. They identify a number of criteria with respect to financial, technical and operational aspects.

The studies show that there is a need for developing a systematic vendor selection process of identifying and prioritizing relevant criteria and evaluating the trade-offs between technical, economic and performance criteria. The approach should also reduce time in vendor selection and develop consensus decision making. In the current studies GDSSs are often proposed as a remedy to overcome the difficulties in supplier evaluation and selection.

Studies in Group Decision Support Systems

In this section, the related studies are stated in a time context and the application areas are discussed. Literature on DSS and GDSS is quite intense.

The earliest studies in GDSS's go back to the late the 1980s. DeSanctis and Gallupe (1987) proposed a framework of three system levels to support group decision.

Specifically, first level GDSS provides technical features, second level GDSS provides decision-modeling and group decision techniques and third level GDSS is characterized by machine-induced group communication patterns. In 1996 Jian Ma develop a group decision support system in order to provide an open and fair method of problem based learning (PBL) assessment. Later, Rao et al. (1997) present a GDSS framework to support Medical Decision Making (MDM) based on cognitive characteristics incorporating clinical reasoning and problem-solving features. Experimental research on Group Decision Support Systems (GDSS) has generally focused on idea generation and choice tasks. The experiments typically consist of groups whose members share the same objectives and do not have a formally designated leader. Barkhi et al. (2001) report on the results of an experiment in which the groups worked on a mixed-motive task. Pervan (1998) address these developmental issues in 1990's through a thorough examination of literature from thirteen core IS and GSS journals. He shows there is a clear need for more field work where studies involving actual stakeholders with their own problem(s) may reveal ways of improving technologies, methodologies and models, or suggesting where new approaches may be needed. Takala (2000) study the usefulness of GDSS in the assessment of customers' needs.

Multiple criteria decision making and GDSS concept has been focused by many researches. Matsatsinis et al. (2001) review some of the past approaches in the multiple criteria - multiple decision makers context and say that GDSS can play a critical role, in decision situations with multiple individuals, each having his/her own private point of view on the handling of the decision problem. In such an environment, the conflict between the members of the group is not a seldom situation. Hamalainen et al. (2001)

describe a framework for multicriteria modeling and support of multi-stakeholder decision processes. Vihakapirom et al. (2003) examine an alternative approach to support dispersed group decision making processes by utilizing Internet technology. They generate a framework to guide the development of a multiple criteria GDSS that can provide a synchronized meeting to geographically dispersed decision makers. An interactive procedure for solving a multiple criteria group decision making problem with incomplete information when multiple decision makers are involved is presented by Kim et al. (1998). I. Ashikhmin and E. Furems (2005) discuss the main ideas of a new approach to discrete multi-criteria comparison and choice from a small set of alternatives and its implementation as the Intelligent Decision Support System UniComBOS. Lu et al. (2005) first propose a rational-political group decision-making model. Based on the model, a linguistic term oriented multi-criteria group decision-making method is developed. They also implement the method by developing a web-based group decision support system. Finally, Geldermann et al. (2009) described the role of multi-criteria decision analysis and revealed that multi-criteria decision analysis was considered to be a suitable framework for supporting, structuring and documenting decision processes, for understanding and bringing together the opinions and perspectives of all participants with diverse background and expert knowledge and for providing transparency within emergency and remediation management.

GDSS have wide areas of application. A field experiment was conducted by Benbunan-Fich et al. (2002) to analyze the process and contents of group discussions. Groups solve a case study either orally or through an asynchronous computer-mediated communication system. Adkins et al. (2002) implemented a group support system (GSS) as a communication tool to facilitate the strategic planning process. The researchers investigate effects of a facilitator's using technology to structure verbal and electronic communication, with the goal of increasing quality output and improving group member satisfaction.

Zhu-Chao and Zhi-Ping (2006) analyzed the main characteristics of the GDM problem in network environment and develop a framework of GDM in network environment. Finally, Simon French explore methodologies for the use of web-based group decision support (wGDSS) and consider the way forward for the design and use of wGDSS and for a more substantive approach to participative e-democracy.

There are also a plenty of papers which describe how effective decision support systems should be designed in terms of environment, communication channels and technology. B. Gavish and J.H. Gerdes Jr. (1998) consider at the issues surrounding anonymity, with particular emphasis on how it may be achieved by using group decision support systems (GDSS) as a backdrop. Sridhar (1998) explore the role of Intranet from a new perspective as a mechanism for supporting decision-making.

There are many studies on web-based decision support systems. Most of them have been conducted in the last decade. In 2004 Mustajoki described the first web-based multi-criteria decision support software called Web-HIPRE, and its use in participatory environmental modeling. In 1998 Chen develops a GDSS for facilitating problem solving by a group of decision makers working together. He focuses on two major aspects of GDSS; human computer interaction and decision making assistance. Basoglu et al. (2001) designed a web based GDSS framework where a pilot study is developed and demonstrate on car selection process. Wei et al. (2001) introduced business intelligence

(BI) methodology into traditional GDSS, and a new agent oriented architecture based on BI that is called BI-GDSS is given out. Dong and Loo (2001) proposed a framework for the architecture of a WDSSG utilizing different software agents to enhance the functionalities of existing DSS. Scenarios and Visualization are incorporated into the DSS for additional functionalities. An Integrated Multimedia based Intelligent Group Decision Support System (IM1GDSS) was presented by Saxena et al. (2002). Wanga and Chien (2003) presented a web-based group decision support system that considers the decision making process as a whole, including idea generation and sharing, planning, discussion, decision inference, and evaluation. The decision support infrastructure is based on agent and object-oriented technology. Hamalainen (2003) presented decision making platforms. It contains much software designed for various needs of decision making. Tiana et al. (2005) proposed an organizational DSS for R&D project selection. Blanninga, and Reinig (2005) presented a framework for using group support systems (GSS) under different conditions of events and time periods. In 2007 the architecture and detailed design of a Web-based GDSS, called TeamSpirit, were discussed to address the challenges of building a Web-based GDSS by Chen et al. (2007). Repoussis et al. (2009) presented a web-based decision support system (DSS) that enables schedulers to tackle reverse supply chain management problems interactively. Huang and Wang (2005) presented GDSS-MC, a group decision support system for enterprises that employ mass customization (MC) strategy.

The comprehensive analysis on DSS & GDSS applications shows that although the applications of GDSS in various areas are numerous, up to our knowledge no application exists in supplier selection area. Substantial modeling studies have been made for supplier evaluation. However they only provide a framework study for the DSS development. Thus there are no implementations by developed software. The originality of this thesis study comes from the fact that such GDSS software is developed in a web-based environment and implemented in a company.

CHAPTER 4:

DEVELOPMENT OF THE DSS MODEL

Based on the common approaches in the literature, supplier evaluation and selection are made by using the AHP methodology. The steps of model development are described below.

AHP Model

The Analytic Hierarchy Process (AHP) developed by Saaty (1980), is a decision making method for prioritizing alternatives where multiple criteria are considered. The approach consists of three hierarchy levels, including the goal, the criteria, and the alternatives. It offers a method the rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extension to which they are met by the alternatives. The AHP uses a principle of hierarchic composition to derive composite priorities of alternatives with associated multiple criteria from their priorities. The priorities are represented using numerical values. It multiplies each priority of an alternative by the priority of its corresponding criterion and adds over all the criteria to obtain the overall priority of the alternative (Hou et al., 2004).

The AHP provides a framework to cope with multiple criteria situations involving intuitive, rational, qualitative and quantitative aspects. It first structures the problem in the form of a hierarchy to capture the basic elements of a problem and then derives ratio scales to integrate the perceptions and purposes into a synthesis. In the hierarchical structure, all the elements in a level are pair-wisely compared with respect to the elements in the level above, and paired comparisons are used to elicit judgments. Then the synthesis of judgments is obtained as a result of hierarchic "re-composition" in order to find the best decision. The AHP is said to be a successful theory because its assumptions are consistent with available experimental data, it makes testable predictions based on experiments, and it explains behavior (Barbarosoğlu & Yazgaç, 1997).

AHP has been studied extensively and used in almost all applications related with multiple criteria decision making (Ho, 2007). AHP has been adopted in finance, education, engineering, government, industry, management, manufacturing, personal, political, socially and sports (Vaidya and Kumar, 2006). It has been used for selection, evaluation, benefit and cost analysis, allocation, planning and development, priority setting and ranking, decision making and forecasting. The wide applicability is due to its flexibility, simplicity and ease of use. The analytic hierarchy process (AHP) can also be very useful in involving several decision-makers with different conflicting objectives to arrive at a consensus decision (Tam & Tummala, 2001). One of the most beneficial features of the AHP method is that it allows group decision making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Brainstorming and sharing ideas and insights often lead to a more complete representation and understanding of the issues (Al-Subhi & Al-Harbi, 1999). Jaganathan et al. (2007) [AHP 31] proposed an integrated fuzzy analytic hierarchy process (AHP) based group decision making approach to facilitate the selection and evaluation of new manufacturing technologies (NMT) in the presence of intangible attributes and uncertainty. Finally, Matsuo and Ito (2002) proposed a decision support system for group buying based on buyers' preferences using AHP as one of the methods.

AHP is a method that is well suited to the supplier selection problem since many tangible and intangible factors exist in the supplier selection procedure. AHP can be used to determine both the importance of weights for criteria and relative ranking of the alternative potential suppliers. The strength of the method lies in its ability to handle the judgmental factors. Narasimhan (1983) reveals some advantages of AHP, when applied to supplier selection problem;

1. It provides a systematic approach that focuses on commonly used evaluation criteria, such as pricing structure, delivery compliance, etc. In contrast to "storing" models, AHP makes it easier for purchasing managers to quantify their subjective evaluations.
2. By using a step-by-step approach to quantification, the difficult task of processing information about vendors is simplified.
3. Although subjectivity is not removed, it is tempered by a more consistent application across alternatives.

He suggests the use of the AHP approach for supplier selection problems mainly because of its inherent capability to handle qualitative and quantitative criteria used in supplier selection problems. Development of the criterion weights and rating and ranking of vendors are accomplished in one integrated procedure which can be easily understood and applied by operating managers.

The AHP can help to improve the decision-making process. The hierarchical structure used in formulating the AHP model can enable all members of the evaluation team to visualize the problem systematically in terms of relevant criteria and subcriteria. The team can also provide input to revise the hierarchical structure, if necessary, with additional criteria. Furthermore, using the AHP, the evaluation team can systematically compare and determine the priorities of the criteria and subcriteria. Based on this information the team can compare several vendor systems effectively and select the best vendor (Tam & Tummala, 2001).

AHP has also found a wide area of application in selection and evaluation problems within various industries. Geldermann et al. (1990) presented an improved methodology for IS project selection using AHP. Lai et al. (1999) discussed multimedia processing environment, the applicability of AHP in problem solving and how AHP can be applied to selection of authorizing systems in a group decision environment. Bevilacquaa and Braglia (2000) applied AHP for selecting the best maintenance strategy for an Italian oil refinery. Ngai (2001) used AHP for a selecting problem - the best web site for online advertising. Byun (2001) used AHP for decision on car purchases. Tiwari and Banerjee (2001) presented an AHP based decision support system to select the most suitable casting process for a given product. Millet and Wedley (2002) proposed methods for modeling risk and uncertainty with the analytic hierarchy process (AHP). Saaty et al. (2007) addressed how to apply the absolute measurement mode of the AHP together with LP to optimize human resource allocation problems. Huizingh and Vrolijk (1995) explored the appropriateness of AHP to support I/S decision making. Ertugrul and Karakasoglu (2007) used fuzzy AHP to evaluate the performance of fifteen Turkish cement firms in IMKB. Sirikrai and Tang (2006) presented an AHP-based model to comprehensively explore the varying degrees of importance of the indicators and drivers of industrial competitiveness. Lee and Kozar (2006) investigate website quality factors and use AHP to determine their relative importance in selecting the most preferred website. Wong and Li (2006) adopt a multi-criteria AHP approach to analyze and select the alternative designs for intelligent buildings.

The AHP modeling process involves four phases, namely, structuring the decision problem, measurement and data collection, determination of normalized weights and synthesis-finding solution to the problem (Tam and Tummala, 2001).

Basically the AHP model which is developed by Saaty (1980) has 10 steps:

1. Defining the problem and the goal.
2. Developing the hierarchy starting from the goal at the top and the alternatives at the bottom level.
3. Preparing pairwise comparison matrices and performing comparisons between criteria and alternatives by using the scale depicted at Table 2 in order to define priorities and importance of each criterion and alternative.
4. Summing up each column in matrices and normalizing the matrices by dividing each cell in the matrices to the sum of corresponding column.
5. In the normalized matrices averaging up each row of criteria and alternatives (calculated values in this phase are priority values of criteria and alternatives, matrix composed of these values is called priority vector matrix).
6. Each priority value within the priority vector matrix of the criteria and alternatives is multiplied by each value of the column within the pair comparison matrix of each corresponding criterion and alternative (values calculated in this phase is called weighted sum matrix).

7. A final matrix is created by summing up of rows within the weighted sum matrix divided by row values of priority matrix prepared at phase5. λmax value is calculated by calculating the arithmetic means of each value in the final matrix.
8. Calculating the consistency index (CI). Consistency check is a capability that distinguishes AHP from other decision making techniques. It is the extent to which each comparison is reliable and coherent. For example, if the choice A is preferred to choice B and choice B is preferred to choice C, then a consistent comparison would be preferring choice A to choice C.
    a. $CI = (\lambda max - n)/(n - 1)$ (1)
9. Consistency ratio (CR) is calculated by using CI and Table 3.
    a. $CR = CI/RI$ (RI = Average random consistency) (2)
    b. In AHP consistency ratio should be below 0.10. Otherwise pair comparison matrices should be reevaluated and steps should be repeated after corrective actions.
10. Final priority values for each criterion are calculated by multiplying alternative priority values by criteria and criterion priorities calculated by performing pair comparisons among criteria.

Table 2. Scale For Comparison of Alternatives

1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Very Strong or Demonstrated Importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2-4 6-8	Intermediate values to reflect fuzzy inputs	Values between the judgments listed above to be used in negotiations
Reciprocals	Reflecting dominance of second alternative compared with the first	

Table 3. Average Random Consistency (RI)

N	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The AHP is one of the extensively used multi-criteria decision making (MCDM) methods. It is a compensatory methodology for evaluation and choice. Based on the vast amount of study in literature, it provides the following advantages:

1. It is aimed at integrating different measures into a single overall score for ranking decision alternatives by its main characteristic which is based on pair-wise comparison judgments (Ngai, 2001).
2. AHP can accommodate both tangible and intangible, individual values and shared values.
3. AHP helps to structure a group decision.
   3.1. The discussion centers on objectives rather than on alternatives.

3.2. Doing so eliminates the need for participants to resort to common simplistic decision strategies (Dyer and Forman, 1992).

3.3. Individual group members with information, knowledge and expertise relative to a specific factor are naturally presented with the opportunity to make their views known.

3.4. Strong members of the group cannot continuously bring the conversation back to their area of expertise.

4. AHP analysis is a structured methodology.

4.1. Every topic or factor relevant to discussion considered respectively and is addressed in turn.

4.2. Because the analysis is structured, discussion continues until all available and pertinent information has been considered and a consensus choice of the alternatives most likely to achieve the organizations stated objectives is achieved (Dyer and Forman, 1992).

There are also some drawbacks of the AHP model.

1. AHP application is time consuming. The model might require a recursive decision process due to inconsistent evaluations therefore evaluators should be trained well (Barbarosoğlu & Yazgaç, 1997). Moreover, the number of pair-wise comparisons is large if the number criteria or alternatives are greater than 7.
2. Many people should be involved in the process especially when a group based problem solving methodology is followed. Therefore managing increasing number of people might become difficult.
3. Huge amount of data is required for better outcomes.

In order to cope with these drawbacks benefiting from information technologies (IT) is crucial. Data retrieval, data processing, data update, resolution and observing the performance and quality of outcomes are some of activities which require high IT involvement.

Supplier Selection Criteria

In constructing the AHP tree structure, the ultimate goal is to develop a model which can be used to solve the supplier selection problem by the firms operating in various industries. The hierarchy developed in this study is a four-level hierarchy in which the top level represents the goal and the last level consists of the alternatives. According to the literature review conducted, a list of the common criteria used to select suppliers in various industries is prepared. In this approach the criteria that are heavily industry-specific are excluded. By doing so, a consolidated supplier selection criteria list is obtained. Therefore the list can be used in the supplier evaluation and selection process regardless of the industry. However, the list might be extended by some industry specific criteria if needed. The resulting criteria hierarchy tree developed for supplier selection is shown in Figure 2.

Constructing, implementing and interpreting the AHP model get harder when the number of sub criteria under each parent criteria increases. To this end, all criteria within the tree are selected according to their ability to show supplier performance for different industries. For example lead time requirements are crucial for many organizations in all industries and used as a critical indicator of supplier's logistical performance.

The key objectives which effect the supplier selection decision are grouped under four categories: logistical performance, business structure, production system and cost.

Evaluation criteria that affect the key objectives are included at the second level. The sub-criteria that are related to second-level criteria, if any, are included at third level. The overall hierarchy constructed is given in Figure 2. Each factor that is included in the hierarchy is briefly described below.

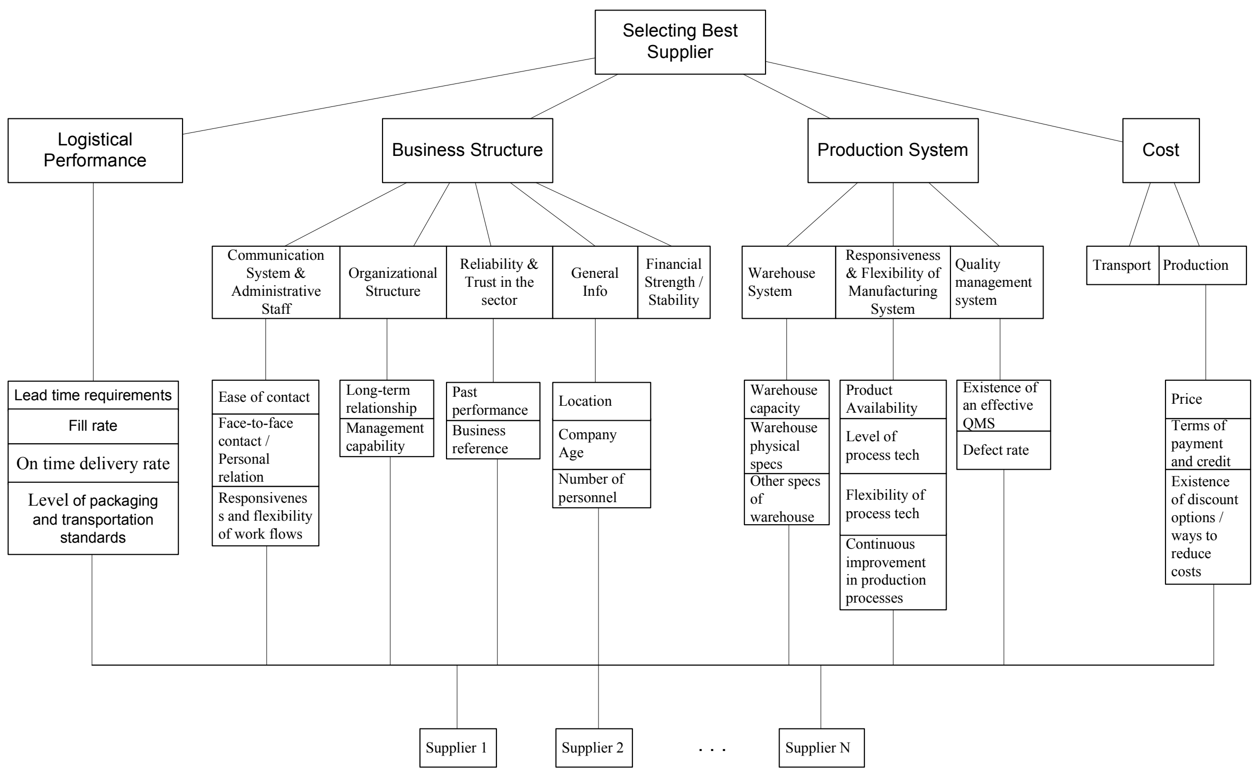


Figure 2. Supplier selection criteria tree

Description of each criterion is as follows.

Logistical Performance: It evaluates the logistical performance of the supplier based on several sub criteria.

- Lead time: The time elapsed between order placement and order receival. Shorter lead times are preferred.
- Fill rate: The ratio of the quantity received to the quantity ordered. The supplier with higher fill rate is preferred.

- On time delivery rate: The extent to which supplier places on-time delivery. It is a very important component of the logistics criterion.
- Level of the packaging and transportation standards: The degree to which packaging materials and techniques as well as transportation style used by the supplier comply with the standards of the company.

Business Structure:

- Communication system and administrative staff: It describes the way supplier manages the relationship with the buyer.
    - Ease of contact: The ability to maintain fast and easy transactions with the supplier by receiving the orders via internet, EDI, telephone etc.
    - Face-to-face contact / personal relation: The opportunity to build direct contact to related parties and chances to have close relationships with the supplier. It also represents the suppliers' ability to provide a relevant contact when needed.
    - Responsiveness and flexibility of work flows: The adaptability of the supplier to changes in purchase quantities and due dates etc.
- Financial Strength / Stability: The level of the supplier's long-term financial strength and its stability ensure that performance standards can be sustained in the future.
- Organizational Structure: It is the suppliers approach to business and business relations. It includes suppliers' business tradition, will, and ways of doing business.

    - Long term relationship: The supplier's willingness and commitment to develop longer-term relationships with the buyers.
    - Management capability: The supplier's overall professional ability to develop a closer working relationship with the buyer.
- Reliability and trust in the sector: The suppliers level of reputation in the sector. It may include historical performance data of existing suppliers or information retrieved from current customers of prospective suppliers.
    - Past performance: The level of past experiences with the supplier.
    - Business reference: The level of business references provided by the supplier
- General Information: The general information of the supplier related to its performance are evaluated
    - Location: The closeness of the location of headquarters office, manufacturing and warehouse facilities of the supplier.
    - Company Age: The total number of working years in the sector, as an indicator of experience and expertise of the supplier.
    - Number of personnel: The total number of personnel of the supplier, as an indicator of size and work capacity of supplier.

Production System:

- Warehouse System:
    - Warehouse capacity: The total capacity of the warehouse in which ordered products are stored and from which they are delivered.

    - Warehouse physical specifications: The existing physical specifications of the warehouse such as humidity ratio, temperature that should be considered according to the storage requirements of the product.
    - Other specifications of the warehouse: The existence of safety regulations, insurance, quantity of maintenance process, handling & transportation.
- Responsiveness & Flexibility of Manufacturing System:
    - Product availability: The ability to increase the production level due to increases in the demand rate. It is the degree to which the supplier can respond to increased demand conditions at all time.
    - Level of process technology: The technology level of the supplier as compared to industry standards. It includes the technology level of machinery, tools and other equipments used to manufacture products.
    - Flexibility of process technology: The ability of the supplier to adapt their technologies to the changing needs of manufacturer. It encapsulates the technological requirements for the production line and the support services.
    - Continuous improvement in production processes: The level of the supplier's continuous efforts on improving its technology and quality standards. As the production goes on, new technical and qualitative requirements are requested by the company and the supplier is asked to meet these requirements.
- Quality management system:

- Existence of an effective QMS: The extent to which the supplier complies with any quality management system including related quality standards and codes.
- Defect rate: The average defect rates of the supplier.

Cost:

- Transport cost: The transportation cost of a single item. This criterion is excluded from total cost of product since transportation can be performed by another party or the company itself. Therefore, its cost and conditions should be considered separately.
- Production costs:
    - Price: The prices of the single item that supplier charges to the company.
    - Terms of payment and credit: The relative level of conditions of the supplier for payment and credits as compared to their suppliers.
    - Existence of discount options / ways to reduce costs: The frequency of generating cost reduction projects by a supplier as compared to the others. Although cost reduction projects are merely submitted by the suppliers, it is a good opportunity to gain cost advantage.

The comprehensive list of supplier selection criteria described above is used to derive the AHP criteria tree. The evaluator is asked to select a set of criteria from this list and form his / her own criteria tree. Then AHP can be applied to evaluate a set of suppliers by this tree as discussed below. In the next section, a GDSS is developed to achieve the involvement of multiple evaluators in a flexible and dynamic environment.

CHAPTER 5:

DEVELOPMENT OF DSS ENVIRONMENT

Technical Background (Architecture)

The architecture of SSES is shown in Figure 3.

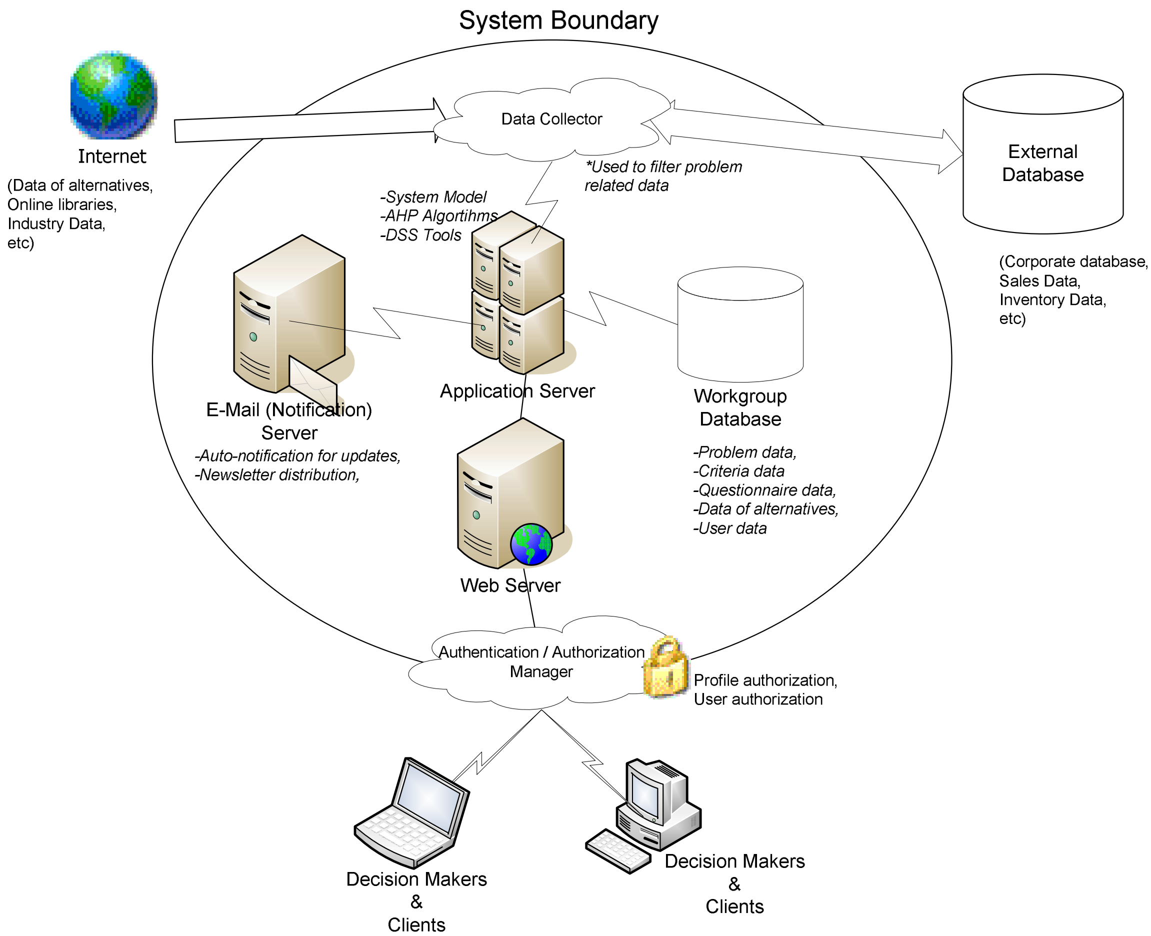


Figure 3. SSES architecture.

GDSS, as a specific type of system within the broad family of DSS, has been successfully implemented in many organizations at different organizational levels. Group members may be distributed in different locations. Therefore a group decision meeting needs web-based tool support (Lu et al., 2005). Therefore SSES is designed as a web-based platform which supports anytime, anywhere concepts. Users can easily access to system by using any internet browser. As shown in figure 3 the system is separated from external system by data collector and authentication / authorization manager.

Data collector is a tool which retrieves relevant data from outside system when needed. External systems could be internet which includes huge data about industry, alternatives (suppliers), or any libraries and corporate database of the organization which stores data of inventory, sales, personnel etc. One-way integration could be built with these systems in order to retrieve data that might be used in the system. Data collector prevents users from entering raw data that already exists somewhere outside. By doing so, users do not spend too much time for data entrance and probability of human error is decreased.

Authentication / authorization manager is the manager which checks whether incoming users' user name and passwords are correct and valid. If so it sends authentication data to authorization manager to create menu hierarchy according to the authorization level of incoming user. Authorization manager adds menu data to user data and sends them to web server.

The web server manages all web pages of the system, traces user information and provides simultaneous services to multiple group members through sessions, applications and cooking facilities. All web pages developed in SSES, for interacting dynamically to group members in solving multi-criteria group decision-making problem are created on the fly by the web server.

Application server includes manager classes which manage all rules, algorithms and calculations, system model, formulas and other decision objects are created, updated and executed by these classes. Application server communicates with workgroup database in order to manipulate problem data, criteria set and criteria hierarchy, supplier data, assignments and evaluation results. Workgroup database only stores data about the decision problem such as problem definition, proposed criteria trees, criteria details, and profile and department assignments of criteria, user comparisons, supplier actual data, and calculated evaluation results.

Another manager that application server connects is notification (e-mail) server. Notification server manages the communication among users, decision makers and suppliers if needed. All updates, task assignments and any other information are notified to related users via e-mail.

Model Base

It is well accepted that DSS applications need some modifications since the information needs of decision makers may change over time. Hence, whatever tool or method is chosen for the building of a DSS, it must be one that adapts well to changes in the databases accessed, the models used, and even the user interface. On the other hand, object-oriented methods seem to provide the best groundwork for systems that need to be changed over time. The most important characteristic that makes the object-oriented methods valuable is reusability so they provide a platform for faster development and maintenance. (Basoglu et al., 2001). Infrastructure of SSES is based on object-oriented technology.

SSES has multi-tier architecture which is a client-server architecture in which the presentation, the application processing, and the data management are logically separate processes. Technology map of SSES is depicted in Figure 4.

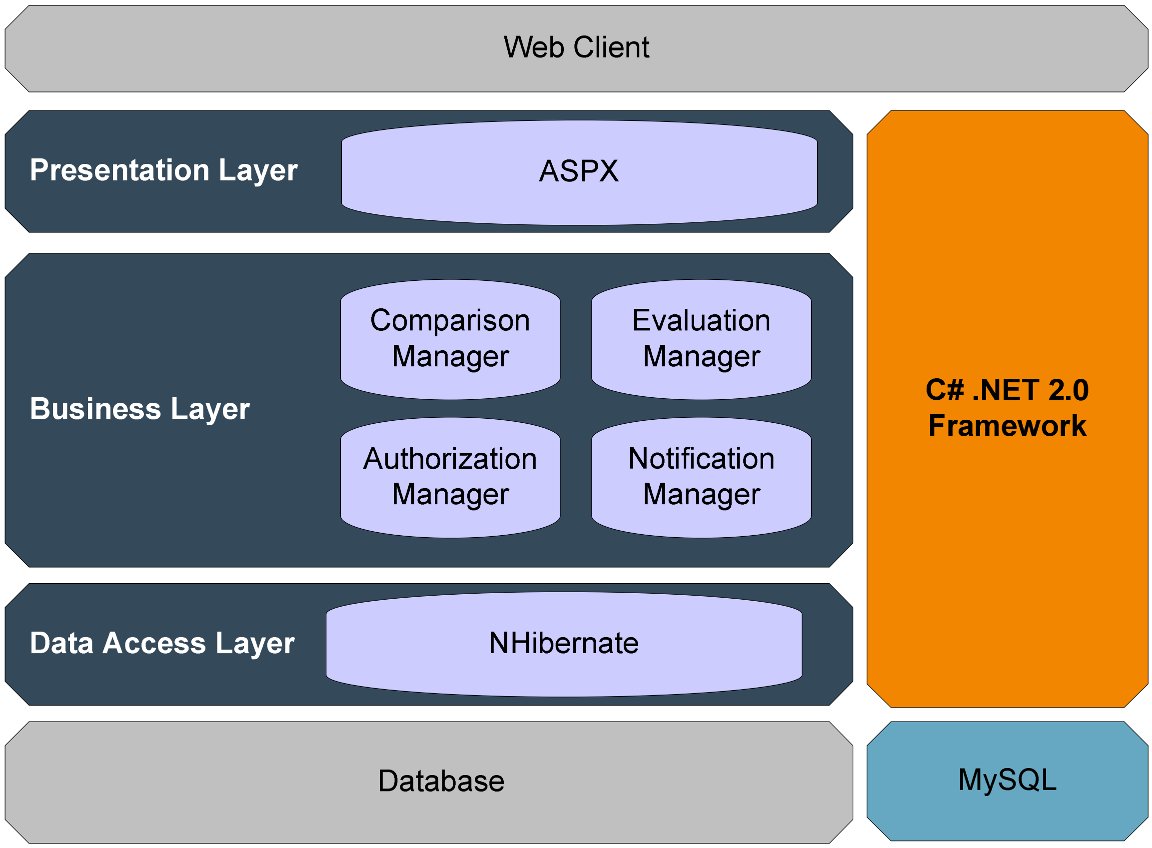


Figure 4. Technology map of SSES

As depicted in figure structure of SSES has five levels each of which performs different tasks. Levels are described in bottom-up fashion.

Database

A relational database is used in SSES. It enables flexibility and clear representation of entities (objects) within the system. Appendix A is provided to depict entity relationships, also database schema, diagram.

MySQL™ is a relational database management system (RDMS) which has been widely used by projects which require a full-featured database management system. The program runs as a server providing multi-user access to a number of databases. MySQL is available under terms of General Public License (GPL). MySQL version 1.2.16 is used in database operations.

Data Access Layer

A Data Access Layer (DAL) is a layer of a computer program which provides simplified access to data stored in persistent storage of some kind, such as an entity-relational database. It acts as a bridge between database and business layer. This data access layer is used in turn by other program modules to access and manipulate the data within the data store without having to deal with the complexities inherent in this access. DAL class diagram is provided in Appendix B.

Hibernate™ is a powerful, high performance object/relational persistence and query service. Hibernate lets develop persistent classes following object-oriented idiom - including association, inheritance, polymorphism, composition, and collections. Just like MySQL Hibernate also has GPL open source license which allows the use of Hibernate and NHibernate in open source and commercial projects. Nhibernate which is a port of Hibernate is an object-relational mapping (ORM) solution for the Microsoft .NET platform: it provides a framework for mapping an object-oriented domain model to a traditional relational database. Nhibernate version 2.0.1 is used in SSES.

Business Layer

Business layer is the layer that compartmentalizes the rules and calculations of a software application from its other design elements. This layer separates the business logic from other modules, such as the data access layer and user interface. By doing this, the business logic of an application can often withstand modifications or replacements of other tiers. Business layer is also called the application layer which is pulled out from the presentation tier and, as its own layer; it controls an application's functionality by performing detailed processing. Appendix C shows the class diagram of SSES.

We used the Microsoft .NET™ framework in the application layer. It is a software framework which includes a large library of coded solutions to common programming problems and a virtual machine that manages the execution of programs written specifically for the framework. Programs written for the .NET Framework execute in a software environment that manages the program's runtime requirements. Architecture of .NET framework supports Common Language Infrastructure (CLI) which is to provide a language-neutral platform for application development and execution, including functions for exception handling, garbage collection, security, and interoperability. We preferred to use C# programming language since it is a simple, modern, general-purpose, object-oriented programming language.

Presentation Layer

This is the topmost level of the application. The presentation layer displays information related to browsing and edited objects. It communicates with other layers by outputting results to the browser/client layer and all other layers in the architecture. It includes interfaces that translate tasks and result in such a way that the user can understand.

Pages in .NET environment are known officially as web forms. They are the main building block for application development. Web forms are contained in files with an ".aspx" extension; in programming jargon, these files typically contain static (X)HTML markup, as well as markup defining server-side Web Controls and User Controls where the developers place all the required static and dynamic content for the web page. We have also used JavaScript in pages in order to create some dynamic functions in the client-side.

Web Client

Web client also known as browser / client layer locates at the top of presentation layer in the architecture. It is not especially one of the core layers of SSES architecture. The layer web client in the figure represents software application for retrieving, presenting, and traversing information resources on the World Wide Web. Browsers are intended to display the information provided by web servers. Since SSES is a web-based platform running on a web server, browsers are needed.

Graphical User Interface (GUI)

Graphical user interface (GUI) is the graphical representation of and interaction with, programs, data, and objects on a computer screen. It presents a visual display of information and object which can present visual feedback to a user. The graphical design of a DSS should be in such a way that user understand and use it easily. One of the definitions of DSS is “A DSS is designed to be easy to use; user friendliness, graphical capabilities, and an interactive human-machine interface greatly increase the effectiveness of a DSS” (Hanna et al., 2004).

GUI design of decision support systems should be shaped according to the user profile of the system. The level of users, the degree of their knowledge about the problem, the terminology they use, and their technical understanding are one of the major parameters in designing GUI of an effective DSS. Potential users of our system are spanning through a large scale of level in organization from operators to managers. However, we assume that they might have no information and experience on AHP method. They also might not be familiar to the data that they would be dealing with in criteria tree development and criteria definitions.

Users use the system in order to complete some particular tasks, and achieve a goal. Therefore the system should direct each user in what and how they have to do. To overcome this problem we put help links in every page which include general information about the page, the meaning of components in the page, the role of that page in the whole picture, and some examples if needed. In addition, there is a list in welcome page which covers all completed and uncompleted tasks in sequential manner.

Another aspect of effective GUI design is clarity. Each component within the page should have description and the functionality of any button or control should be clear to the user. Also there should be separation between navigational and functional buttons [DSS 54]. To this end, we labeled each component in pages meaningfully so that their functionality is clearly understood. Required fields are marked with a star. In case of any error system warns user about what (s)he did wrong and what (s)he needs to do to correct the problem by pointing the related component(s) causing the error. For instance, if the user left a required field, let say department name, blank, the system warns by the message “Department Name should not be blank. Please enter Department Name.” and a pointer appears near Department Name field.

Another point in GUI design is consistency. “A user will be inclined to interact with an interface according to how they are expecting it to be. That is, they may expect some input prompt, button locations, and viewable options based on their familiarity with working with the problem or with other interfaces. It is important that within your application, or across similar applications, some features of the user interface are consistent" (Hanna et al., 2004). In our system all components are ordered logically in each page they are located. For instance, in department definition page department name field is followed by department description field. This logic repeats in all definition pages. However, buttons like "OK" and "Cancel" are at the same place (left bottom of the page) in every page they are included.

CHAPTER 6:

IMPLEMENTATION OF DSS ENVIRONMENT

Basic flow of transactions to produce a supplier ranking in SSES is depicted in Figure 5. Huang & Wang (2005) argued that there are two kinds of user roles in decision group members, the decision maker and the project facilitator. Decision makers are group members who are usually experts in particular domains and are selected and invited by the Project Facilitator to join the decision project. Project Facilitator is the initiator of the decision project, who can be considered as the project manager of the team and will be hosting the project during the whole group decision period. In addition to those decision makers' responsibilities, the project facilitator has special privileges to manage the project, e.g. to organize the virtual team by selecting group members, to make agenda and control project progress, to conduct group meetings and complete the final decision report, etc.

However, Basoglu et al. (2001) proposed a framework in which the group leader (modeler, or domain leader) is separated from other users in DSS. In their framework the group leader determines a domain (car selection, laptop selection etc.), alternatives, group members, and their relative weights. Then each member picks a subset of model criteria among the whole set, then determines his personal weights.

There are two types of users in SSES: the group leader (moderator) and the group member (decision maker), moderator is responsible for facilitating the supplier evaluation process by completing main definitions such as signing up users, creating departments, profiles, products and suppliers. Moderator also defines the evaluation term intervals in which decision makers propose criteria, assign priority and evaluate suppliers.

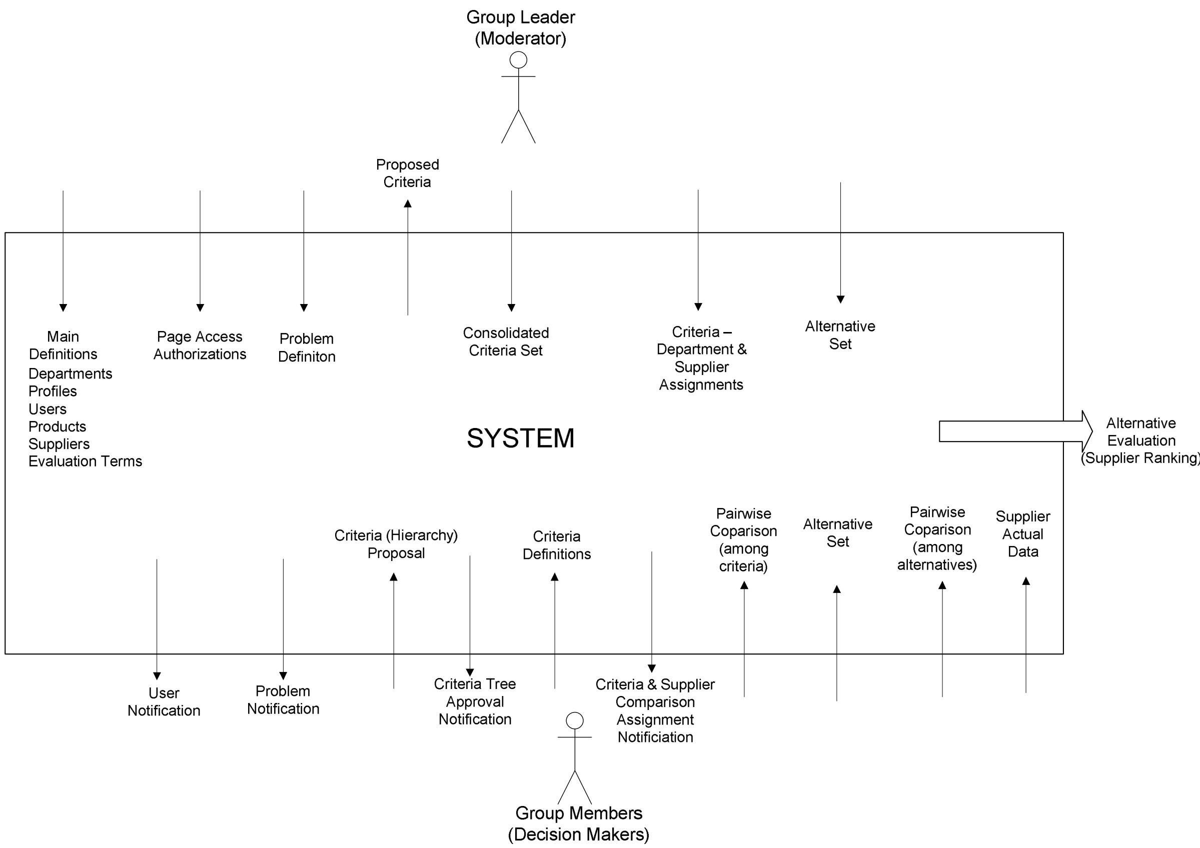


Figure 5. Basic flow of the system

Group members are the people from various domains and titles within the organization who are eligible for defining criteria for supplier selection and making judgments on current and prospective suppliers according to the given criteria set.

In figure activities at top side are mainly related to definitions of entities, and consolidating data (idea) provided by the users (decision makers). Group facilitator (moderator or leader) is responsible from this type of tasks. The moderator directs users by assigning tasks. S/he also could set access authorizations of each user.

This section is to provide an overview of the system functions which are used to implement these tasks.

Preparation of Pilot Study

A pilot study has been conducted in the construction industry. Four decision makers from different departments have been involved in the system. Four decision makers from different departments, which are logistics, purchasing, production and quality and finance, were involved in pilot study. Four suppliers are selected to be evaluated, for privacy concerns they were represented as ABC Co, GGG Co, XYZ Co and WWW Co. One construction material which is supplied by both these suppliers is considered in comparing the suppliers. Before the pilot study was conducted, an introduction meeting was arranged in which decision makers are trained for the system and AHP methodology. Criteria within the default criteria tree (see Figure 2) have been explained one by one in order to provide a common understanding on the criteria tree. Full flow of operations in Figure 5 has been tested in pilot study. All operations and how they are performed in SSES is described in next sections. Most of the illustrations are the outputs of pilot study.

Initial Definitions and Login

Effective supplier selection process has to involve decision makers from various backgrounds. Since suppliers are evaluated against multi criteria and evaluating each criterion requires different expertise and experience, decision makers have to be grouped accordingly. There are two types of grouping in SSES; departments and profiles. Departments classify decision makers by domains such as quality, marketing, finance etc whereas profiles focus on expertise and experience of each decision maker. To this end, each decision maker's department and profile have to be defined by the moderator so that they can participate in the decision making process.

Decision makers log into the system with a username and password (see Figure 6).

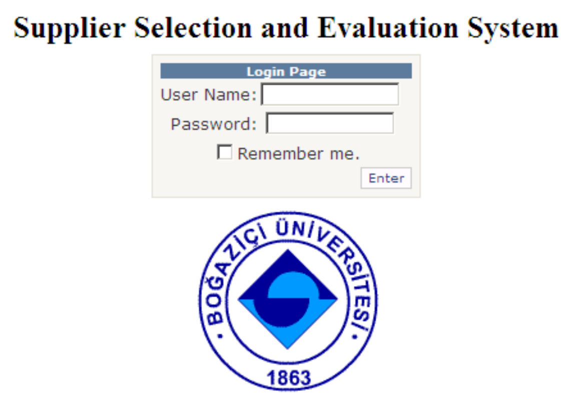


Figure 6. Login page

The system checks the credentials and redirects to home page after checking authorization details of the user to define the menu items which include the pages that the user have access right (see Figure 7).

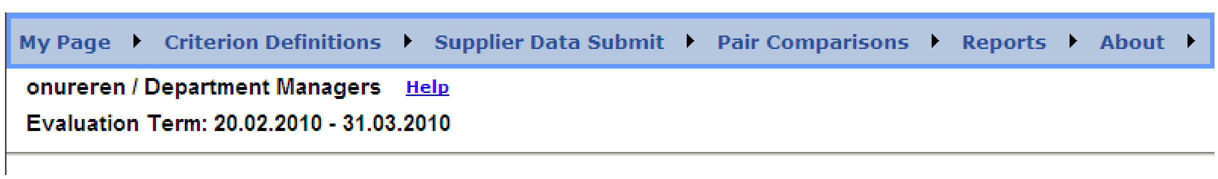


Figure 7. Home page

Menu items on the top of the page can vary for different users based on authorization definitions. Username, active profile of the user and current evaluation term details are displayed on the top left of the home page.

Constant Definitions

Before the evaluation problem has been defined and process has been initiated, some definitions, called constant definitions, have to be completed. These definitions include the creation of following entities within the system.

Profile Definitions

The process of GDM is very complicated. It is composed of multiple stages and is participated in by multiple groups. The expert or group who offers preference information is often different in different stages (Zhu-Chao & Zhi-Ping, 2006). In SSES users (decision makers) are grouped in two entity, profile and department. Profiles are authorization levels which are to separate users in terms of authorizations. There may be a group leader or leaders who play more important roles than others in a particular group decision-making. Group members have different weights in a group decision-making, and the situation should be reflected on the generation process of the group satisfactory decision (Lu et al., 2005). Profiles in SSES are used to assign role (weight) to users.

Figure 8 depicts the profile maintenance and detail pages where profiles are listed, added or updated.

	Profile Name	Profile Description	Number of Users
○	Admin Profile		1
○	Department Managers		6
○	Operators		3

Update   Add New

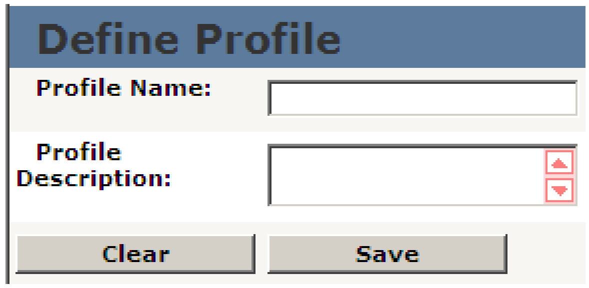
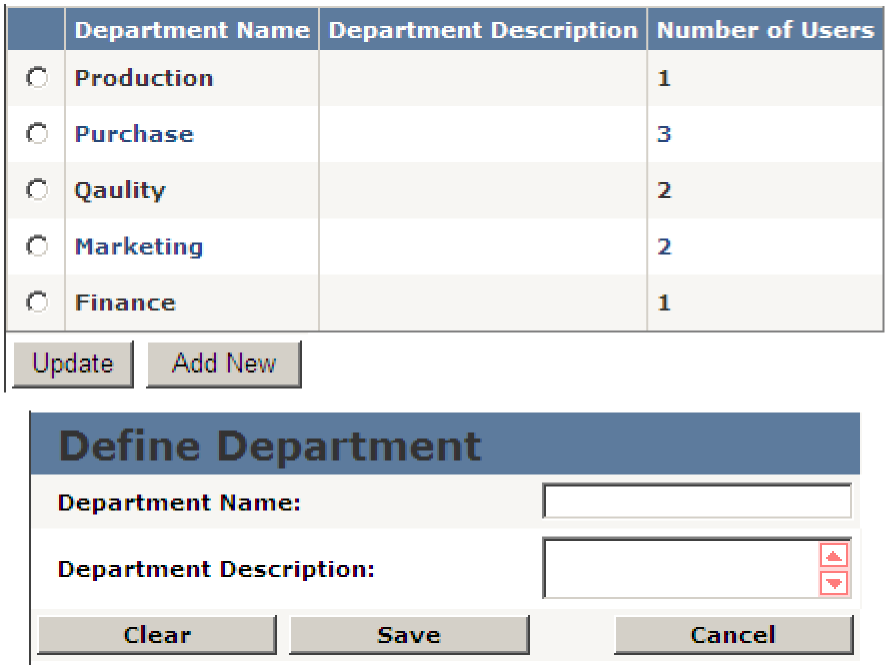


Figure 8. Profile maintenance and details screens

Department Definitions

The second entity that we generated to classify users is department. It is the entity that represents some functional units within organization. As each department has unique functions and responsibilities to reach organizational goals, they have different point of views to the problems. Lu et al., (2005) argues that group members may not know all information related to a decision problem or may not consider all relevant information to the decision problem. Also, they may have different understanding for same information, different experience in the area of current decision problem, and, therefore, different preferences for alternatives. The different preferences of group members impact directly on the deriving of the group optimal decision. By the existence of both departments and profiles the SSES enables different view points, experience, preferences and knowledge to be merged.

Figure 9 depicts department maintenance and details screen where department are listed, added and updated.



	Department Name	Department Description	Number of Users
○	Production		1
○	Purchase		3
○	Qaulity		2
○	Marketing		2
○	Finance		1

Figure 9. Department maintenance and details screens

<u>User Definitions</u>

Each actor in decision making process is represented by users in the system. Figure 10 shows the list of users and how they are defined in the system.

	User Name	Profile Name	Department Name	E-Mail Address
○	user1	Departman Müdürleri	Üretim	
○	user2	Departman Müdürleri	Lojistik	
○	user3	Departman Müdürleri	Satin Alma	
○	user4	Operatörler	Finansman	

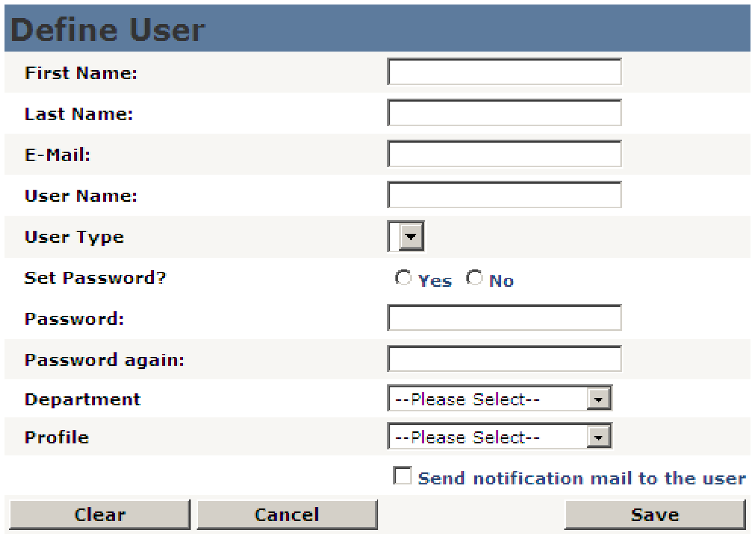
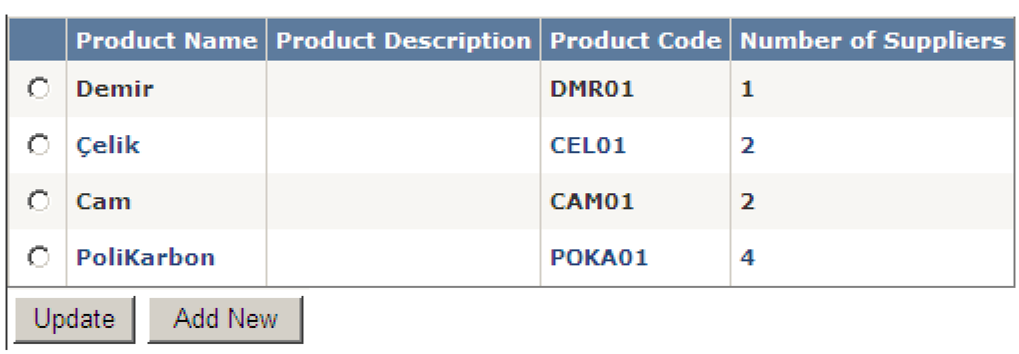


Figure 10. User maintenance and details screens

In order to log in to the system, the user shall have a valid user name and password. Also each user (decision maker) shall have a department and profile as described in previous sections. This information is managed via these pages. Email information is to notify the users thru emails. Users are informed about assignments or data updates by the system.

Product Definitions

Product information which is supplied by suppliers is defined in pages shown in Figure 11. In evaluation phase, these products are used, especially for evaluating product specific criteria.



	Product Name	Product Description	Product Code	Number of Suppliers
○	Demir		DMR01	1
○	Çelik		CEL01	2
○	Cam		CAM01	2
○	PoliKarbon		POKA01	4

Update | Add New

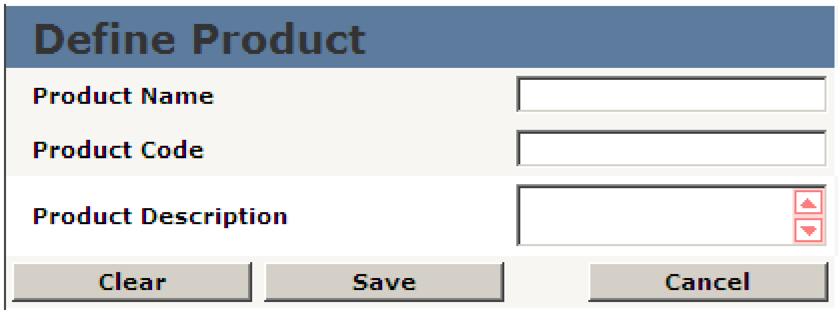
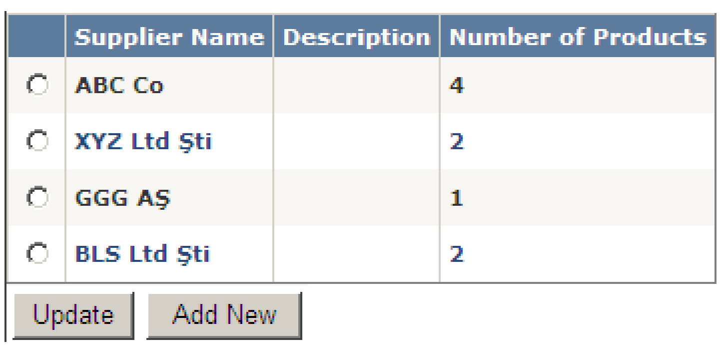


Figure 11. Product maintenance and details

Supplier Definitions

All suppliers, both existing and prospective ones, which would be evaluated are defined in the pages shown in Figure 12. Suppliers are also matched with products which they supply in this page. Suppliers and their corresponding products information within the evaluation pages are retrieved from ones which are defined here.



	Supplier Name	Description	Number of Products
○	ABC Co		4
○	XYZ Ltd Şti		2
○	GGG AŞ		1
○	BLS Ltd Şti		2

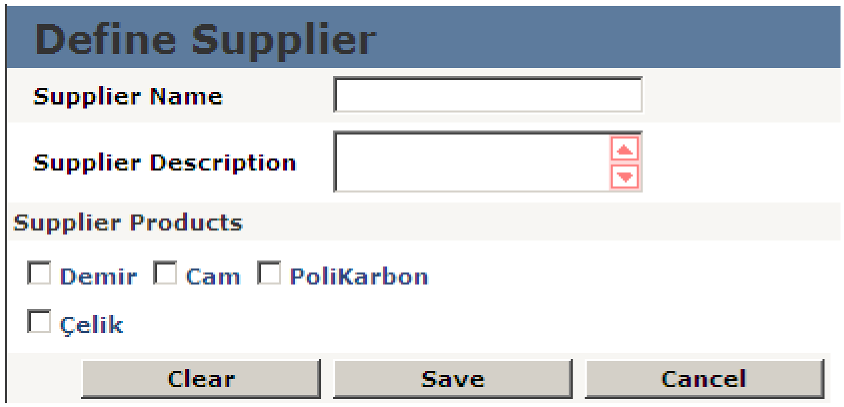


Figure 12. Supplier maintenance and details

When a supplier is left or quits supplying some products, it also has to be removed from the system or products have to be deselected via this page.

Evaluation Term Definitions

Supplier selection process is not a onetime evaluation. Actually the performance of suppliers should be continually traced in fixed time intervals to achieve stability of the system goals. To this end, evaluation term concept is introduced which is used to define the time interval in which criteria set would be decided and evaluations are made by decision makers. In addition, actual performance data of suppliers which corresponds to this time interval would be taken into account. Figure 13 depicts the definition screen of evaluation pages.

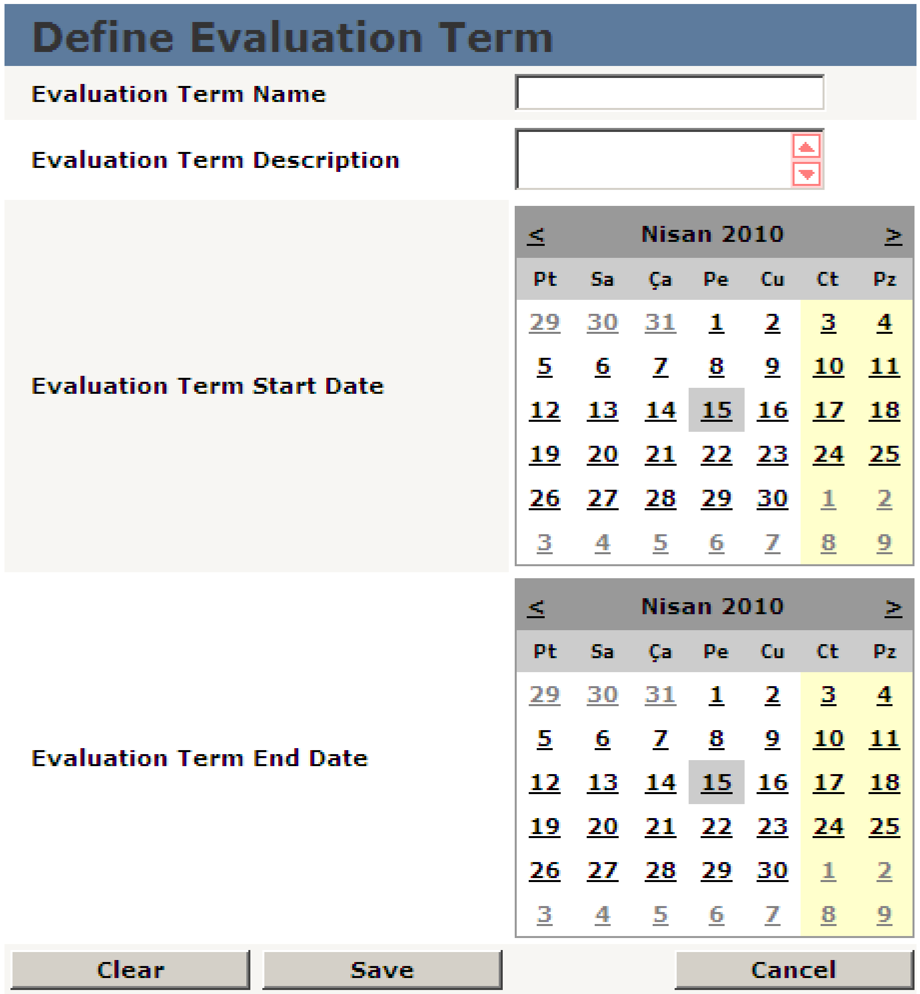


Figure 13. Evaluation term definitions

The system prompts defining new evaluation terms, if there is no active evaluation term at a time. Every transaction in the system is stored with evaluation term information and each criterion, comparison and evaluation has the evaluation term field in database.

Page Access Authorizations

Page authorization section allows defining which pages can be accessed by which user profiles. The page is used basically to match the pages within the system and profiles which are predefined by the user or moderator (see Figure 14). For example, users of a low-level profile do not desired to access all pages. However they might be only allowed to compare criteria assigned to them and might not be allowed to propose a criterion or criteria tree. Therefore pages used in order to define new criterion or to build a new criteria tree should not be matched to this profile.

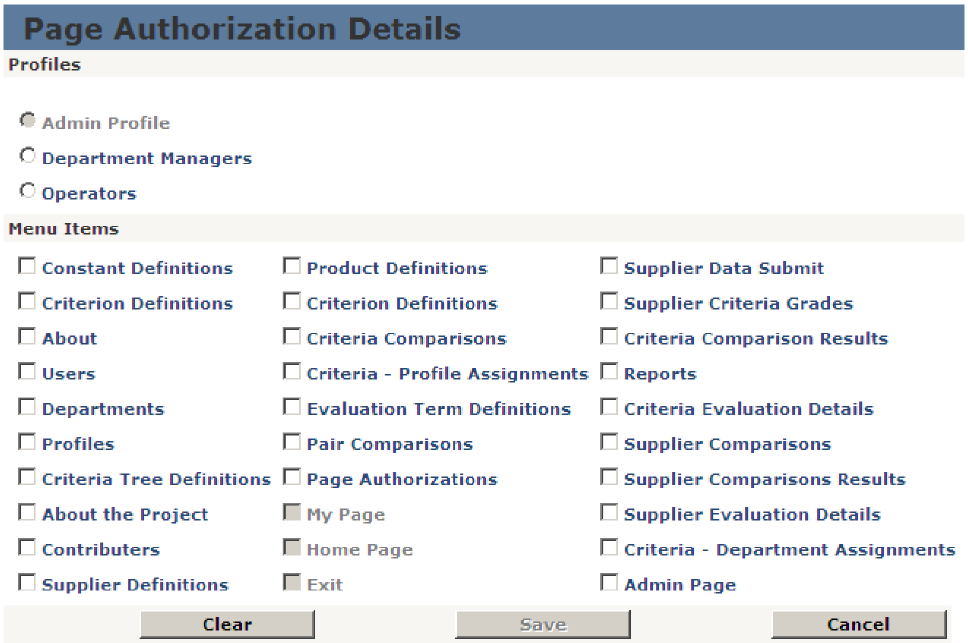


Figure 14. Page access authorizations

Each time a user logs into the system, authorization manager checks authorized pages according to the profile of the user and prepares the menu hierarchy. Therefore unauthorized users do not see the pages for which they are not allowed to access in the menu.

Forming Criteria Tree

Initially, decision makers have to define a set of criteria which will be used in supplier evaluation. The AHP uses a principle of hierarchic composition to derive composite priorities of alternatives with associated multiple criteria from their priorities. Therefore all criteria should be organized as a hierarchy which corresponds to criteria tree in SSES. Criteria tree in Figure 2 is provided as a sample tree (see Figure 15) and each decision maker can build her own tree by adding and / or removing a criterion.

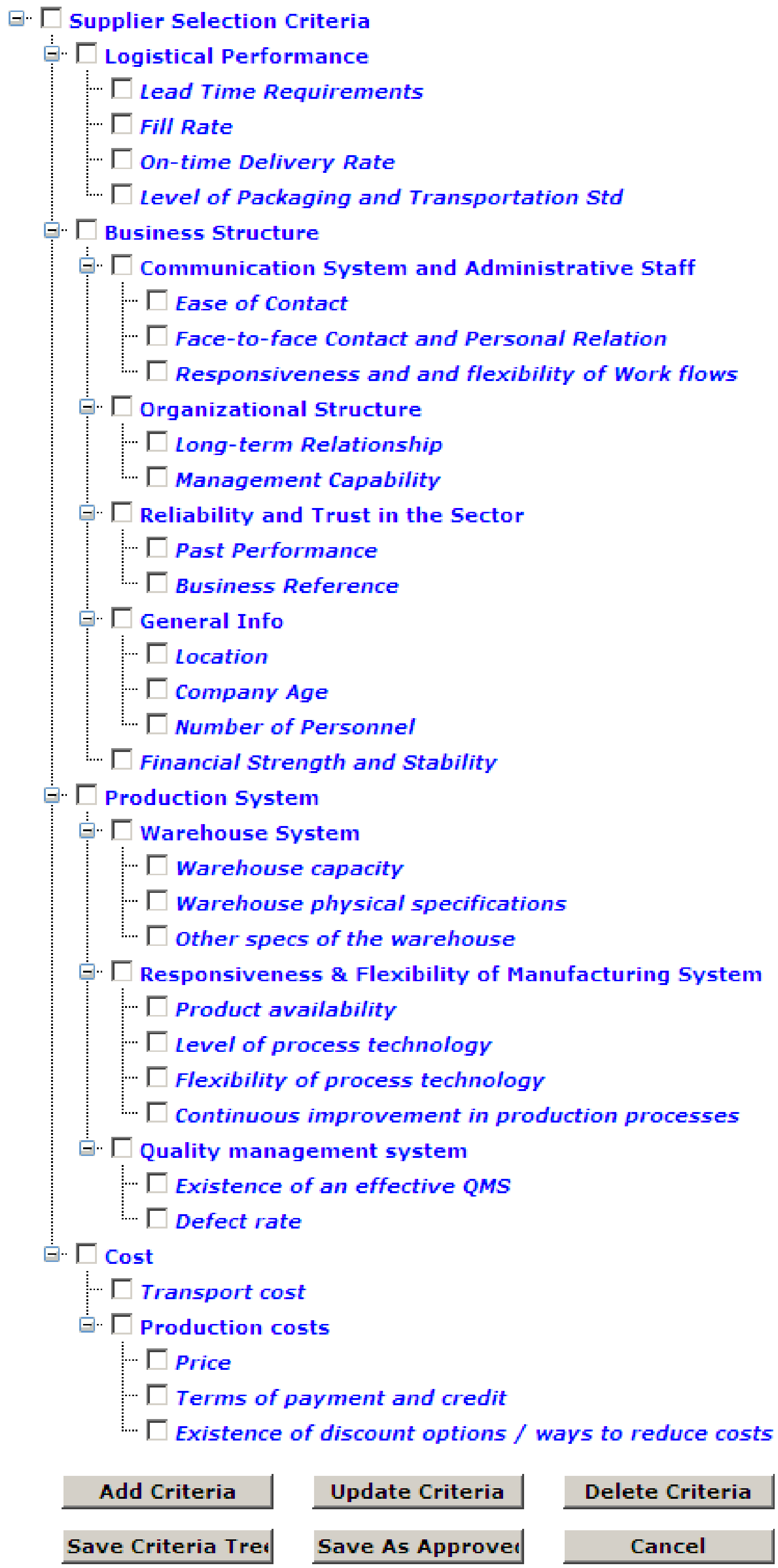

Supplier Selection Criteria
Logistical Performance
Lead Time Requirements
Fill Rate
On-time Delivery Rate
Level of Packaging and Transportation Std
Business Structure
Communication System and Administrative Staff
Ease of Contact
Face-to-face Contact and Personal Relation
Responsiveness and and flexibility of Work flows
Organizational Structure
Long-term Relationship
Management Capability
Reliability and Trust in the Sector
Past Performance
Business Reference
General Info
Location
Company Age
Number of Personnel
Financial Strength and Stability
Production System
Warehouse System
Warehouse capacity
Warehouse physical specifications
Other specs of the warehouse
Responsiveness & Flexibility of Manufacturing System
Product availability
Level of process technology
Flexibility of process technology
Continuous improvement in production processes
Quality management system
Existence of an effective QMS
Defect rate
Cost
Transport cost
Production costs
Price
Terms of payment and credit
Existence of discount options / ways to reduce costs
Add Criteria
Update Criteria
Delete Criteria
Save Criteria Tre
Save As Approve
Cancel

Figure 15. Add / edit criteria tree

Zhu-Chao & Zhi-Ping (2006) argued that as one of the most important characteristics of practical group decision making process as in network environment, all kinds of preference information provided by experts come from multiple stages and multiple groups. So, it needs to aggregate or synthesis the all preference information, to analysis the consensus of GDM and to select the most desirable alternative. In SSES each user proposes his/her criteria set and hierarchy as criteria tree. The moderator explores these criteria trees and consolidates them by combining similar criterion into one and excluding repetitive ones.

After criteria tree is built, the user submits the tree to final evaluation. Moderator checks all submitted criteria trees in terms of similarity, consistency, and ability to reflect organization's expectation and creates the final criteria tree that will be used to evaluate suppliers in that evaluation term. By doing so, every decision maker makes a contribution in building the tree and the final tree reflects the views of all different domains. For each evaluation term a new criteria tree is created because criteria or the place of criteria in hierarchy can vary from time to time.

Defining Criteria Details

Not all criteria are evaluated in the same way. Some criteria should be measured specifically to a product whereas some are not. For example, the performance of a supplier for lead time requirements criterion may differ between products. Therefore these criteria should be evaluated at the product level. But ease of contact of a supplier is same for all products and can be evaluated for once for a supplier. In addition to this, criteria can also be grouped according to their tangibility. Some criteria such as price and defect rate are quantitative and can be evaluated quantitatively. But the reputation criterion is qualitative and should be evaluated rather subjectively.

SSES enables decision makers to group the criteria by their tangibility and define whether they are evaluated at the product level (see Figure 16). If a criterion is quantitative then a scale showing the evaluation ranges should be provided by an expert in order to measure the performance.

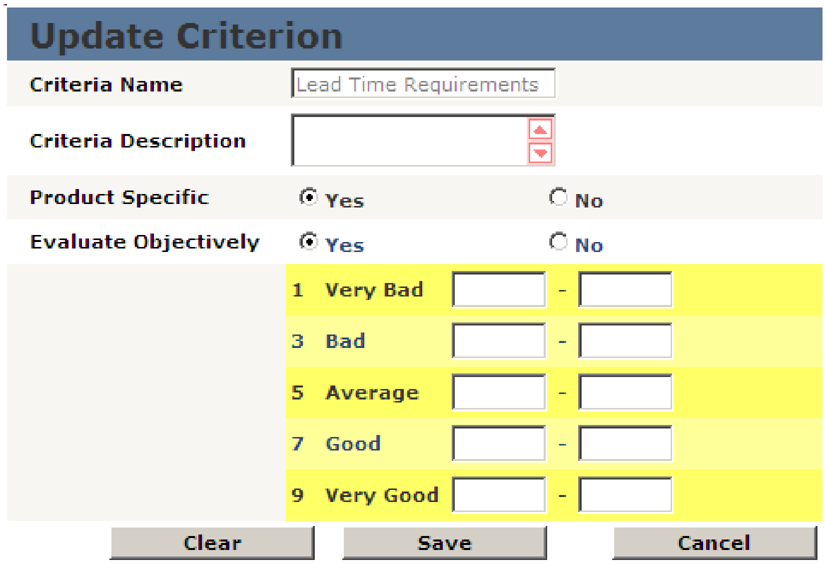


Figure 16. Criteria details

Details of all criteria within the criteria tree have to be defined to proceed to the next step.

Özyörük and Özcan (2008) use AHP to select suppliers among a number of alternatives. They defined five levels as “Very Bad”, “Bad”, “Average”, “Good”, and “Very Good” for some of the product groups. Corresponding values for each level have been developed by conducting a study with the participation of executives of company in which the research is focused on. For each level priority levels of AHP Pair Comparison Scale (1-9 scale) are settled respectively. They aimed at creating comparison matrices more consistently and rapidly.

In other words, a quantitative criterion, such as price, does not need to be evaluated by decision makers on pair-wise comparison basis since cheaper price is preferable over expensive ones. The only thing that decision makers (experts) need to do is defining the scale from very bad to very good for each criterion that is to be evaluated objectively. After the scales are set and lower and upper values are entered, system automatically compares suppliers by matching the values in scales with the actual data entered in “Supplier Grade Details Page”.

Assigning Criteria to Profile / Department

Van de Water and van Peet (2007) propose that each performance aspect is associated with a function within the company. In other words, after defining the set of performance factors, the relevant value chain activities are identified. There is a relationship between each area and each performance objective via its indicators on the previous level. A pair-by-pair comparison of business areas should be made with respect to all performance indicators.

One of the factors that Lu et al. (2005) propose regarding to the decision makers’ opinion is criteria for assessing alternatives. Assessment-criteria are usually determined through generation and discussion in decision groups. Goals or priorities of decision objectives are often as assessment-criteria for multi-objective decision problems. In a real situation, different group members may have different viewpoints in assessment-criteria for a decision problem because of workload, time and inexperience at assessing a problem all affect determining assessment-criteria. Different members may often have different judgments in comparing the importance between a pair of assessment-criteria.

Obviously, what assessment-criteria are used and how priority of each assessment-criterion is will directly influence the selection of the group's satisfactory decision.

SSES enables associating the criteria with departments and/or profiles (see Figure 17). Namely, some criteria within the criteria tree may be assigned to departments and/or profiles for evaluation. For example all criteria under the criterion of "Production System" can be assigned to the production department whereas criteria under the criterion "Price" can be assigned to the finance department. On the other hand, these assignments can be done to profiles as well. For example, criteria under the criterion "Business Structure" can be assigned to department managers profile is which composed of individuals with higher authority, and probably, deeper expertise. By letting each decision maker evaluate only a related set of criteria on her own domain and expertise, one of the major drawbacks of AHP method which is the need to complete huge number of comparisons is overcome.

System sends notification mails to corresponding decision makers to complete the comparisons when assignments are competed.

In the pilot study, criteria were assigned to departments by considering the relevance of each criteria group. Logistical performance criterion and all sub criteria were assigned to the logistics departments, business structure criterion and all sub criteria were assigned to the purchasing department, production system criterion and all sub criteria are assigned to the production and quality department, and finally cost criteria is assigned to the finance department with all sub criteria.

Figure 17. Assign criteria for comparisons

Making Pair-wise Comparisons

After all criteria assignments are completed, decision makers are expected to make criteria and supplier comparisons. Criteria comparisons are to define the priority of each criterion within the criteria tree. Decision maker is asked to compare all assigned criteria in a pair-wise fashion (see Figure 10).

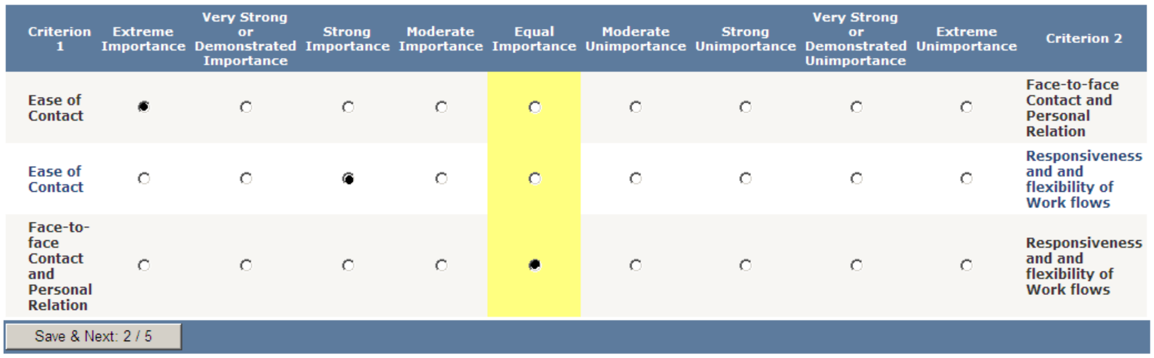


Figure 18. Pairwise criteria comparisons

Each row represents a pair of criteria and each radio button represents an importance level. The nine-point scale as suggested by Saaty (Tama and Tummala, 2001) is used to make pair-wise comparisons of all elements in each level of the hierarchy. For example, if decision maker chooses “Extreme Importance” on the left hand side, she denotes that criterion 1 has extreme importance on criterion 2. The yellow column denotes that two criteria have equal importance and it is the symmetry axis, values on the right hand side reflect dominance of second alternative compared with the first.

Sub criteria under each main criterion are listed in a separate matrix and the decision maker navigates to the next main criterion when all comparisons are done in the current matrix. If there are missing comparisons and / or consistency ratio of comparisons is not acceptable, the system warns decision maker to review her comparisons.

After the criteria weight assignments are made, the next step is to compare the suppliers with respect to each qualitative criterion respectively (see Figure 19).

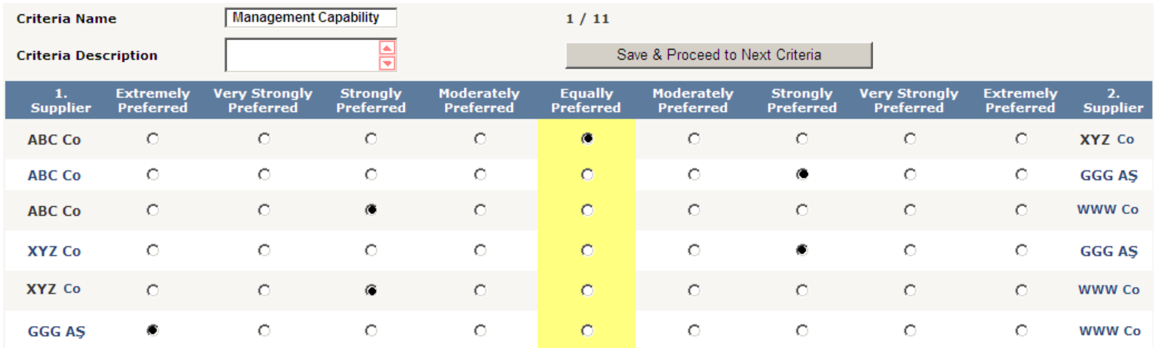


Figure 19. Pairwise supplier comparisons

Each row represents a pair of suppliers and each radio button represents the level of preference. For example, if a decision maker chooses "Extremely Preferred" on the left hand side in the first row, she denotes that ABC Co is extremely preferred to XYZ Co. for the criterion on the top left of the page, i.e., the management capability. The yellow column denotes that two suppliers are equally preferred (have the same performance for the criterion) and it is the symmetry axis, values on the right hand side reflecting dominance of second alternative compared with the first.

Each supplier comparison matrix is composed of suppliers to be evaluated for a single criterion, therefore total number of matrices that decision maker has to fill is as much as the number of qualitative criteria assigned to her. Similar to criteria comparisons the system warns the decision maker to review her comparisons if there are missing comparisons and / or consistency ratio of comparisons is not acceptable.

Each radio buttons within the matrix corresponds to a value in 1-9 scale of Saaty. For instance if user selects the "Equal Importance" which is just in the middle, systems translates it into numeric value, which is 1, and put it to the pair-wise comparison matrix. All verbal values and their corresponding numeric values are given in Table 4 and Table 5. Verbal values show differences according to the compared entities. If criteria are compared than it means importance of each criterion is evaluated and to stating the order of criteria is aimed. But while comparing suppliers the aim is to prefer one supplier to another by taking their performance under consideration. Thus, in criteria comparison table the term "Importance" is used whilst the term "Preferred" is used in supplier comparison table.

Table 4. Verbal and Corresponding Numeric Comparison Values for Criteria

Verbal Values (English)	Numeric Values
Extreme Importance	9
Very Strong or Demonstrated Importance	7
Strong Importance	5
Moderate Importance	3
Equal Importance	1
Moderate Importance	1/3
Strong Importance	1/5
Very Strong or Demonstrated Importance	1/7
Extreme Importance	1/9

Table 5. Verbal and Corresponding Numeric Comparison Values for Supplier

Verbal Values (English)	Numeric Values
Extremely Preferred	9
Very Strongly Preferred	7
Strongly Preferred	5
Moderately Preferred	3
Equally Preferred	1
Moderately Preferred	1/3
Strongly Preferred	1/5
Very Strongly Preferred	1/7
Extremely Preferred	1/9

Although values in the table seem the same, they are located symmetrically in comparison table. The "Equal Importance" column, depicted with another color, is axis of symmetry. For instance, if the user checks the radio button in the second column s/he denotes that criterion 1 has "Extreme Importance" over criterion 2. Checking radio button in tenth column denotes criterion 2 has “Extreme Importance” over criterion 1. Only one radio button could be selected within a row that represents a comparison between two criteria. Therefore the values in two different sides of symmetry denote different numeric values as shown in Table 5. Usually, every decision maker makes his or her pair-wise comparisons, which will be translated into the corresponding pair-wise comparison matrices given in Table 6. These pair-wise comparison matrices then transformed into priority vector matrices in which priority vector of each criterion are calculated given in Table 7. Finally, priority vector matrices are used to created weighted sum matrices given in Table 8. By using these three matrices λmax, consistency index (CI) and consistency ratio (CR) are calculated.

For the sake of illustrating the calculations of priority vectors and consistency index, example in Figure 18 is used. AHP evaluation is performed by using the steps introduced in Chapter 3, AHP Model section. Step 1 and 2 were defining the goal and developing the hierarchy, which are completed by forming criteria tree and making assignments.

Step 3, as shown in figure user is asked to compare three criteria; “ease of contact”, “face-to-face contact and personal relation” and “responsiveness and flexibility of work flows”. There are three comparison pairs for the user to give preferences in order to compare these three criteria. Each comparison user made is converted to number according to 1-9 scale of Saaty and pair-wise comparison matrix is generated. As the user thinks that the criterion “ease of contact” has extreme importance over “face-to-face contact and personal relation” s/he checks the radio button just under the term “Extremely Important” which is closer to “ease of contact”, indicating that its preferred. This comparison is reflected to pair-wise comparison matrix as putting "9" to the cell in which "ease of contact" and "face-to-face contact and personal relation" corresponds as given in Table 6. Each comparison within comparison table is converted to number and put in pair-wise comparison table accordingly.

Table 6. Pair Wise Comparison Matrix

	Ease of contact	Face-to-face contact	Responsiveness & Flexibility
Ease of contact	1	9	5
Face-to-face contact	0,11	1	1
Responsiveness & Flexibility	0,2	1	1
Sum	1,31	11,00	7,00

Step 4, after pair-wise comparison matrix is prepared, the priority vector matrix is needed to be generated in order to calculate the priority vector of each criterion as shown in Table 7.. Cells in priority vector matrix are calculated by dividing each number in cells in pair-wise comparison matrix to the sum of corresponding column. For instance in pair-wise comparison matrix the cell in which "face-to-face contact" and "ease of contact" intersects, which is 0.11, is divided by 1.31 which is the sum of that column. The result, 0.085 is placed again in cell in which those two criteria intersect in priority vector matrix. The priority vector matrix is completed in the similar way.

Step 5, finally, priority vector of each criterion is calculated by calculating the average of each row in the priority vector matrix. Priority vector of criteria shows the weight of importance of each criterion.

Table 7. Priority Vector Matrix

	Ease of contact	Face-to-face contact	Responsiveness & Flexibility	Priority vector
Ease of contact	0,763	0,818	0,714	0,765
Face-to-face contact	0,085	0,091	0,143	0,106
Responsiveness & Flexibility	0,153	0,091	0,143	0,129

Step 6, before calculating consistency ratio a third matrix is needed which is called weighted sum matrix as shown in Table 8. Values in both pair-wise comparison matrix and priority vector matrix are used in generating weighted sum matrix. Comparison values of each criterion within pair-wise comparison matrix is multiplied by the priority vector of that criterion and placed to corresponding cell in weighted sum matrix. The sum of each row is calculated which will be needed to calculate λmax.

Table 8. Weighted Sum Matrix

	Ease of contact	Face-to-face contact	Responsiveness & Flexibility	Sum
Ease of contact	0,765	0,956	0,644	2,364
Face-to-face contact	0,085	0,106	0,129	0,320
Responsiveness & Flexibility	0,153	0,106	0,129	0,388

Step 7; before calculating λmax, ratio between priority vector and sum of weighted sum matrix rows for each criterion is calculated as shown in Table 9.

Table 9. Calculated Values to For Consistency Ratio

	Priority Vector (PV)	Sum of WSM Rows (SWSMR)	Ratio (SWSMR / PV)
Ease of contact	0,765	2,364	3,091
Face-to-face contact	0,106	0,320	3,014
Responsiveness & Flexibility	0,129	0,388	3,013

Step 8; after generating all these matrices λmax, consistency index and consistency ratio could be calculated according to the findings of these matrices.

1 Lambda max

$$\lambda \max = \frac{\sum_{k=1}^{n} (SWSMR_k / PV_k)}{n} \quad (1)$$

2 Consistency index

$$\text{Consistency Index (CI)} = \frac{(\lambda \max - n)}{n - 1}$$ where n is the number of criteria which are compared. (2)

3 Consistency ratio

$$\text{Consistency Ration (CR)} = \frac{CI}{RI} \quad (3)$$

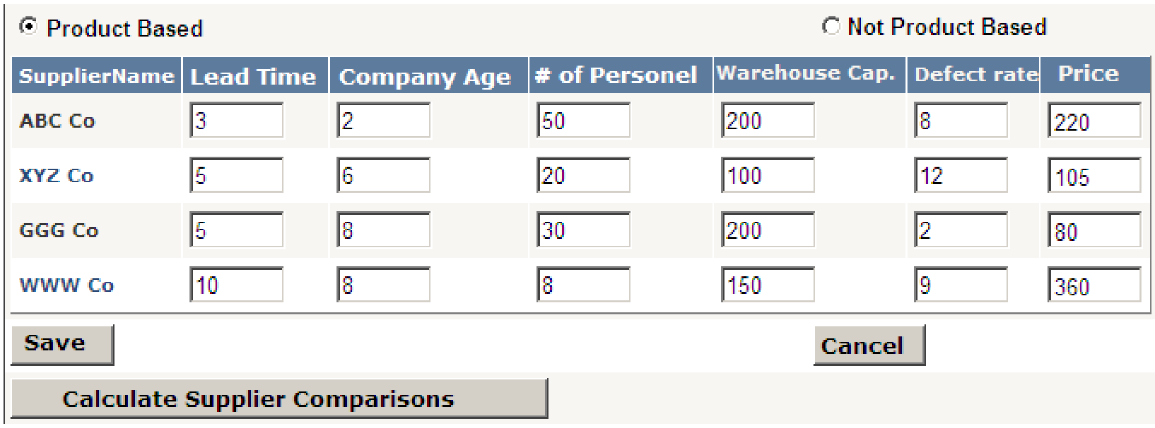
Step 9; by using formula 1 and formula 2, λmax is 3.04 and CI is 0.02. RI is 0.58 which is standard values and derived from table 2, it is average random consistency index which depends on the number of criteria compared. Finally CR is 0.03 by using formula 3. According to the given results these six comparisons seem consistent since a consistency ratio below the value of 0.1 is counted as acceptable.

For each comparison set, the system calculates the consistency ratio in the same way. If the ratio is greater than 0.1 than the system warns the user and asks to reconsider the comparisons until they are calculated as consistent. Otherwise the system saves the user's comparisons and prepare next comparison table by including the criteria which are in the next level in criteria tree.

The same logic and calculations are valid for supplier comparisons. For supplier comparisons user compares the suppliers in pair-wise fashion on the criteria which are set to be evaluated subjectively. Finally the system saves all comparison pairs and priority vectors. These comparisons are later used in simulation pages for monitoring and reporting criteria importance weights and supplier orders.

Supplier Performance Data Entrance

In SSES, as clarified in Criteria Details Definition page, criteria are classified into two groups as 'to be evaluated quantitatively' and 'to be evaluated qualitatively'; quantitative criteria are ones which have to be evaluated based on actual data. If the suppliers which are to be evaluated are current suppliers, their data on related criterion could be retrieved from corporate database, and from past transactions. Otherwise, if suppliers are new and do not have any past transactions data, performance data on related criterion could be retrieved from supplier itself, and / or from its business references. The page used to enter suppliers' actual performance data on criteria that are set to be evaluated objectively are shown in Figure 21.



Product Based | Not Product Based

SupplierName	Lead Time	Company Age	# of Personel	Warehouse Cap.	Defect rate	Price
ABC Co	3	2	50	200	8	220
XYZ Co	5	6	20	100	12	105
GGG Co	5	8	30	200	2	80
WWW Co	10	8	8	150	9	360

Save | Cancel

Calculate Supplier Comparisons

Figure 20. Supplier actual performance data submission

As shown in figure there is a matrix table in which columns represent criteria and rows list the suppliers for which performance will be evaluated through comparison. User enters data that indicates the performance of supplier on given criteria. For instance, for the criterion "lead time", the user enters lead time duration values of all suppliers for a given product (or in general). An illustrative example is given according to the samples values in Figure 21 and Figure 22. In Figure 21, lead time requirements are entered by the user for each supplier. These values will then be converted to comparison table by using the scales generated by the experts as shown in Figure 22 (see Appendix F for the scales of all quantitative criteria).

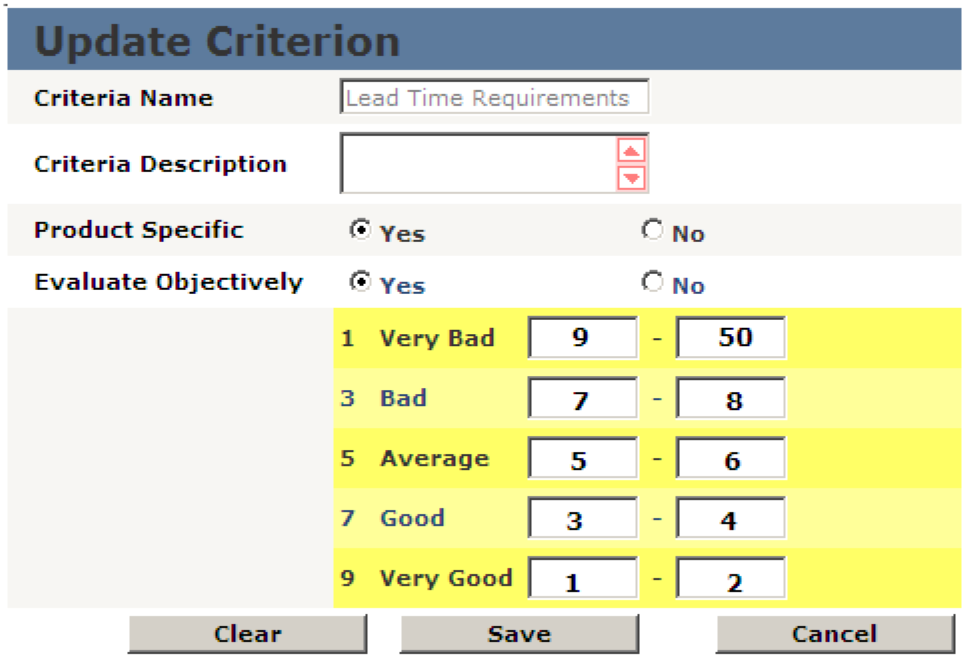


Figure 21. Criteria details

In the criteria details definition page (see section 6.1.5.) experts determined the scale for criteria which ought to be evaluated objectively (quantitatively). Therefore upper and lower bounds of performance levels of each criterion became clear. Now the system matches this scale with the actual performance data of each supplier. Suppliers' performance data on each criterion is checked according to scale and comparisons between suppliers are made automatically by the system. For instance in figure 21, performance level bounds for the criterion "Lead Time Requirement" are set and actual data for the same criteria of each supplier is also entered. Average lead time duration of ABC Co is 3 days which corresponds to "Good" in scale and has a value of 7. Lead time performance of XYZ Co is 5 day which corresponds to "Average" in scale and has a value of 5. These values are converted to comparison values by using Table 10.

Table 10. Scale to Comparison Value Matrix

Supplier1 Performance / Supplier 2 Performance	1	3	5	7	9
1	1	0.33	0.20	0.14	0.11
3	3	1	0.33	0.20	0.14
5	5	3	1	0.33	0.20
7	7	5	3	1	0.33
9	9	7	5	3	1

The comparison value of two suppliers against a criterion is the value in the cell which is the intersection of first supplier's performance and second supplier's performance in the matrix. If suppliers' performance values are in the same interval in scale (figure 21) then the comparison value is 1, which corresponds to "Equally Preferred".

Therefore the comparison value between supplier 1 and supplier 2 is 3 which is the intersection of 7 and 5 in Table 10. It means that Supplier 1 is "Moderately Preferred" to supplier 2 for "lead time requirement" criterion (see Table 5). Lead time requirement performance of GGG Co is also 5 days which corresponds to "Average" and 10 days for WWW Co which corresponds to "Very Bad". Thus XYZ Co is "Equally Preferred" over GGG Co. and "Strongly Preferred" over WWW Co which has numeric values of 1 and 5 respectively. All suppliers and criteria in the table are completed in this way and system automatically generates a comparison table for these suppliers shown in Figure 22. These are virtual tables and not displayed to the user.

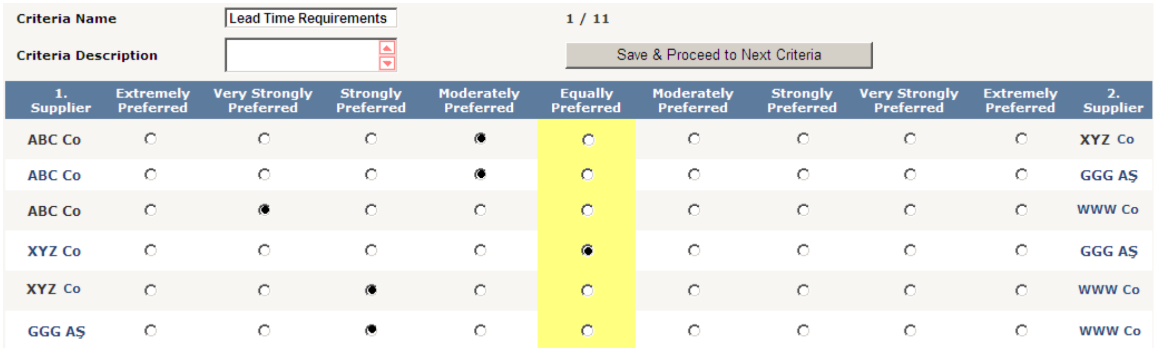


Figure 22. Supplier comparisons against criteria

This table is generated for each criterion and for all suppliers in this way. Calculations described in section 6.1.7 are also applied for these comparison tables (see Table 10, Table 11, Table12 and Table 13 for details of a sample criteria comparison). The comparison pairs and priority vectors calculated according to these pairs are saved in the database.

Table 11. Automatically Generated Pair Wise Comparison Matrix for "Lead Time Requirement" criterion

Criteria	ABC Co.	XYZ Co.	GGG Co.	WWW Co.
ABC Co.	1	3	3	7
XYZ Co.	0.33	1	1	5
GGG Co.	0.33	1	1	5
WWW Co.	0.14	0.2	0.2	1
Sum	1.81	5.20	5.20	18.00

Table 12. Automatically Generated Priority Vector Matrix for "Lead Time Requirement" criterion

Criteria	ABC Co.	XYZ Co.	GGG Co.	WWW Co.	Priority vector
ABC Co.	0.554	0.577	0.577	0.389	0.524
XYZ Co.	0.184	0.192	0.192	0.278	0.212
GGG Co.	0.184	0.192	0.192	0.278	0.212
WWW Co.	0.079	0.038	0.038	0.056	0.053

Table 13. Automatically Generated Weighted Sum Matrix for "Lead Time Requirement" criterion

Criteria	ABC Co.	XYZ Co.	GGG Co.	WWW Co.	Sum
ABC Co.	0.524	0.635	0.635	0.370	2.164
XYZ Co.	0.175	0.212	0.212	0.264	0.862
GGG Co.	0.175	0.212	0.212	0.264	0.862
WWW Co.	0.075	0.042	0.042	0.053	0.212

Table 14. Automatically Calculated AHP values

	Priority Vector (PV)	Sum of WSM Rows (SWSMR)	Ratio (SWSMR / PV)
ABC Co.	0.524	2.164	4.131
XYZ Co.	0.212	0.862	4.074
GGG Co.	0.212	0.862	4.074
WWW Co.	0.053	0.212	4.018

λmax is calculated as 4.074, consistency index is 0.024 and random consistency index is 0.90. According to these values the consistency ratio is calculated as 0.027 which is much smaller than 0.1. That proves the consistency of comparisons which are automatically made by considering actual supplier data and criteria performance bounds.

Reports

This section of SSES enables users to monitor all evaluations based on the comparisons and actual performance data of suppliers made so far. This page also provides tools for “what-if” analysis. Ultimate output of the system which is a list in which all suppliers are ordered according to the given priorities, proposed criteria set and weights assigned to particular profiles and / or departments, is produced in this section. This section is used to perform these simulations and produce final reports. Figure 23 depicts the “Criteria Evaluation Details” page.

In principal, the user faces to only the part marked with the blue rectangle (numbered as 1). This part lists all evaluation terms, profiles and departments defined so far. User first selects the evaluation term which s/he wants to work with. As mentioned in the “Constant Definition” section, evaluation terms need to be defined at the beginning of the system. Each criteria proposal, criteria and supplier comparison and supplier performance data entrance are occurred in an evaluation term which has a starting and end date and encompasses the current working days. Thus, the first thing the user selects is the evaluation term.

After the evaluation term is decided, user has to determine whether evaluations are used by considering profiles, departments or both. By checking “Evaluate by Profiles” and / or “Evaluate by Departments” profile and department lists become enabled to select which profiles and departments will be included in evaluation. Each time the user checks profiles and department users defined under selected profiles and departments are listed in the part marked with the red rectangle (numbered 2). These users are ones which have contributed to determining final the criteria tree of organization by making criteria comparisons. If both profiles and departments are selected user list includes the user which are defined under both selected profile and departments (intersection is taken). After the user finishes determining which profiles and departments would be included in the evaluation some evaluations of users could be excluded in this part by not selecting (not checking) those users. Each time a user is selected, criteria table and constructed criteria tree appearing in the part marked with green rectangle (numbered as 3). For instance, if only one user is checked then the criteria tree, appeared on right hand side, reflects the preferences of selected users only. When more than one user is checked the system constructs the criteria table and criteria tree by calculating arithmetic mean of priority vectors of each criteria by the preferences of selected users.

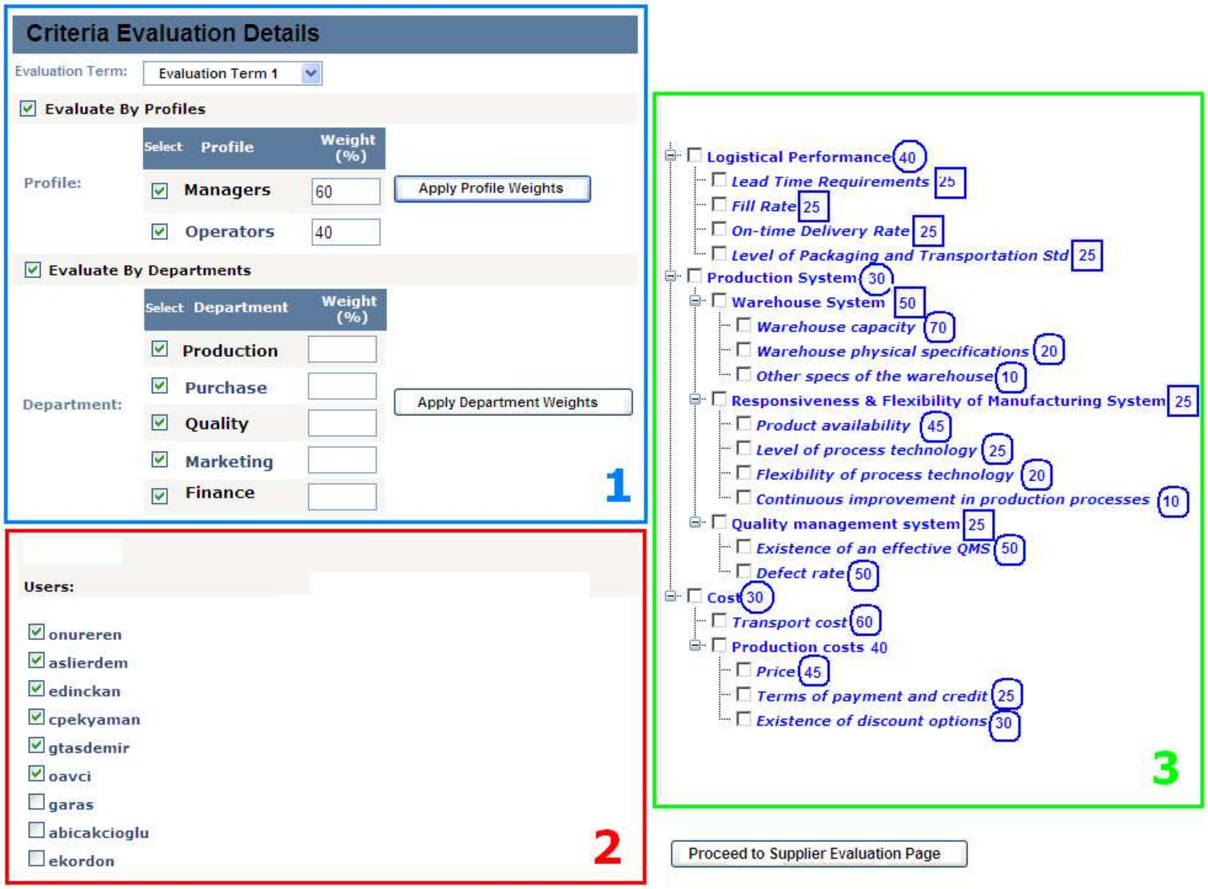


Figure 23. Criteria evaluation report filter

Finally, the criteria tree constructed by including the preferences of selected users could be reshaped by assigning different weights to profiles or departments. For instance if the user wishes to assign more importance to the profile “Department Managers” over “Department Operators” (s)he enters the corresponding values to the text boxes near the profiles and clicks “Apply Profile Weights”. Certainly the sum of entered weights should be equal to 100 otherwise the system warns the user to recheck the weights accordingly. One critical point to be considered in this section is that in order to assign different weights to different departments and/or profiles, all criteria have to be evaluated by at least more than one user. If not, some parts of the criteria tree which is being built on right hand side might be missing or misleading since assigned weight would reduce the priority vector of the selected users. To this end, “Apply Weight” buttons and weight textboxes are not displayed, if there isn’t sufficient evaluation to apply weights.

All these operations are to construct a criteria tree in which importance weights are assigned by including and excluding profiles, departments and even users. After final constructed tree is agreed the user clicks “Go to Supplier Evaluation Page” button to fix the criteria tree and use this tree in supplier evaluations. “Supplier Evaluation Details” page, as seen in Figure 24, is similar to Criteria Evaluation Details page. The difference is on the left hand side of the previous page the criteria tree is fixed. Similarly the evaluation term and the criteria tree selection at the top of the page are disabled since they were selected in the previous page. Selection of profiles and departments as well as including and excluding user preferences are just the same as the Criteria Evaluation Details page. But this time supplier evaluations (comparisons) of the selected users are taken into account. As mentioned in previous sections users are asked to compare suppliers in pair-wise fashion on criteria that are set to be evaluated subjectively. Not surprisingly, priority vectors of supplier comparisons are used in arithmetic mean when more than one user is selected.

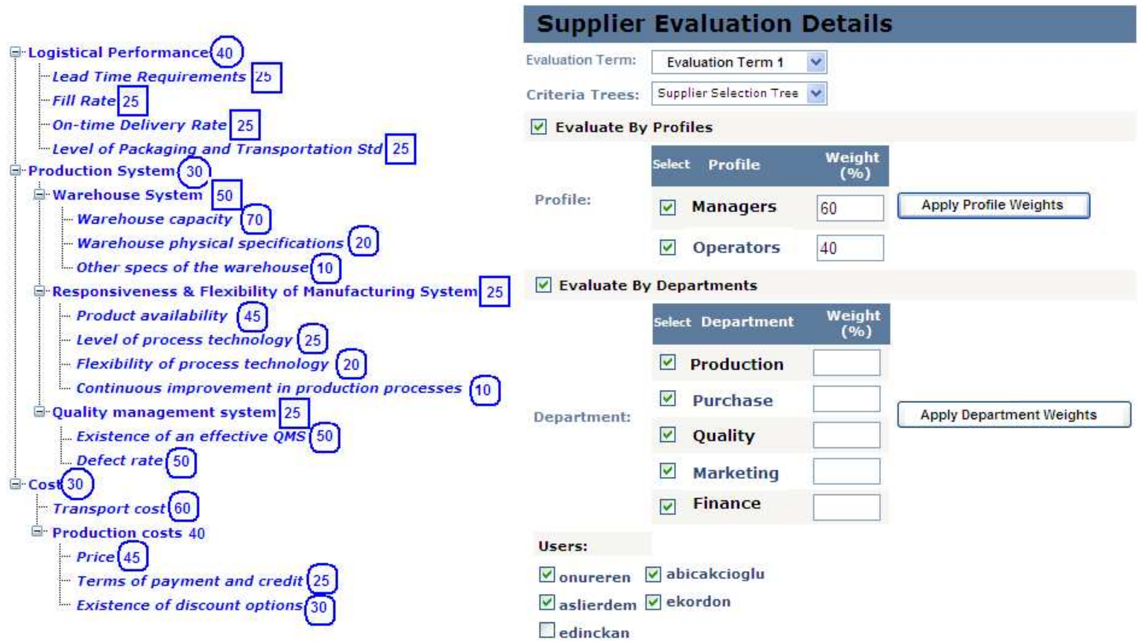


Figure 24. Supplier evaluation report filter

The total evaluation report which is shown in Table 14, is re-generated each time a new user preferences is included in evaluation.

Table 14 is the content of the "Criteria Weights and Supplier Evaluations" report where criteria weights and supplier evaluations are shown. All criteria comparisons made by decision makers are included in the report. Criteria weights are depicted under "Criteria Weights" column. The report shows that most important criterion in supplier selection is "Cost" with 55 % weight following by "Production System", "Business Structure" and "Logistic Performance with the weights of 21%, 15% and 9% respectively. Weights of sub-criteria can also be monitored from the report.

Table 15. Criteria Weights and Supplier Evaluations Report

Supplier Selection Criteria	Criteria Weights	XYZ Co	GGG Co	ABC Co	WWW Co	TOTAL
OVERALL EVALUATION	1.00	0.22	0.35	0.24	0.18	1.00
Logistical Performance	0.09	0.24	0.19	0.44	0.12	1.00
Lead Time Requirements	0.15	0.21	0.21	0.52	0.05	1.00
Approp. Of the Quantity	0.44	0.24	0.12	0.60	0.03	1.00
Approp. Of the Delivery Date	0.37	0.25	0.25	0.25	0.25	1.00
Packaging and Trans. Stds	0.04	0.25	0.25	0.25	0.25	1.00
Business Structure	0.15	0.23	0.22	0.37	0.15	1.00
Comm. System and Admin. Staff	0.25	0.25	0.16	0.53	0.05	1.00
Ease of Contact	0.22	0.30	0.30	0.30	0.10	1.00
Face-to-face and personal communication	0.45	0.24	0.12	0.60	0.03	1.00
Responsiveness and Flex. Of Work Flows	0.32	0.24	0.12	0.60	0.03	1.00
Organizational Structure	0.16	0.25	0.19	0.43	0.14	1.00
Long term relationship	0.50	0.25	0.25	0.25	0.25	1.00
Management Capability	0.50	0.24	0.12	0.60	0.03	1.00
Reliability & Trust in Sector	0.19	0.21	0.21	0.52	0.05	1.00
Past Performance	0.50	0.21	0.21	0.52	0.05	1.00
References	0.50	0.21	0.21	0.52	0.05	1.00
General Info	0.19	0.20	0.35	0.12	0.33	1.00
Location	0.22	0.25	0.25	0.25	0.25	1.00
No of working years in the sector	0.65	0.17	0.40	0.04	0.40	1.00
No of personnel	0.13	0.30	0.30	0.30	0.10	1.00
Financial Strength and Stability	0.19	0.25	0.25	0.25	0.25	1.00
Production System	0.21	0.13	0.51	0.20	0.16	1.00
Inventory Management System	0.09	0.28	0.30	0.30	0.12	1.00
Warehouse Capacity	0.09	0.10	0.30	0.30	0.30	1.00
Warehouse Physical Specs	0.25	0.30	0.30	0.30	0.10	1.00
Other Specs of Warehouse	0.66	0.30	0.30	0.30	0.10	1.00
Responsiveness and Flex. Of Manufacturing Sys	0.25	0.16	0.27	0.29	0.27	1.00
Product Availability	0.04	0.21	0.21	0.52	0.05	1.00
Level of Process Technologies	0.12	0.25	0.25	0.25	0.25	1.00
Flexibility of Process Technologies	0.25	0.25	0.25	0.25	0.25	1.00
Continuous Improvement in Production Processes	0.58	0.10	0.30	0.30	0.30	1.00
Quality Management System	0.66	0.09	0.62	0.16	0.12	1.00
Existence of an Effective QMS	0.17	0.30	0.30	0.30	0.10	1.00
Defect Rate	0.83	0.05	0.69	0.13	0.13	1.00
Cost	0.55	0.24	0.35	0.19	0.20	1.00
Transportation Cost	0.10	0.17	0.40	0.04	0.40	1.00
Production Cost	0.90	0.25	0.35	0.21	0.18	1.00
Price	0.32	0.27	0.56	0.13	0.04	1.00
Terms of Payment and Credit	0.45	0.25	0.25	0.25	0.25	1.00
Existence of Discount Options	0.22	0.25	0.25	0.25	0.25	1.00

For example, “Production Cost” is the most important aspect within the “Cost” criterion with the weight of 90%. “Payment options and installments” is the most crucial among other criteria which are under “Payment options” criterion. Other columns in the report represent the supplier and their corresponding weights for each criterion. As mentioned previously, these weights are calculated by considering only the comparisons of users and weights of criteria are not applied to them.

Each supplier’s weight against each criterion is shown in the corresponding columns of suppliers. If a criterion has sub criteria, then the total weight is calculated by multiplying each sub criteria weight with the weight of suppliers for that sub criterion. Overall evaluation which represents the ultimate weights of each supplier is given in first row. Results show that GGG Co. is the first supplier with the weight of 35%, followed by ABC Co, XYZ Co and WWW Co with the weight of 22%, 12% and 18% respectively. When the report is examined it is seen that GGG Co is not best at all criteria. For instance, in terms of logistical performance ABC Co is the best with the weight of 44%, GGG Co is the third one. The weight of logistical performance criterion, which is the lowest among others, is not enough to put ABC Co to first position. That’s why ABC Co is the first ranked supplier although ABC Co is the best at logistical performance and business structure. GGG Co, is the first ranked supplier because it performs well in terms of production system and cost which are the top two criteria in weights.

This report provides a good understanding of the comparison of suppliers for each criterion. Suppliers can figure out their strengths and blind points in this table. However the evaluator company itself can find many useful facts from the report. It can trace which criteria have been used and their corresponding weights. It can also compare the total number of criteria and change of weights of each among different evaluation terms. Therefore, both the evaluator company and suppliers can benefit this report to shape their roadmaps.

Evaluation of DSS Tool

Computer based systems DSS tools, like SSES, are being used in many industries and organizations. The accurateness of the operations of the tool is often critical for business success. Developing or selecting these types of systems is therefore of prime importance. Comprehensive features and evaluation of software product quality is a key factor in ensuring adequate quality. This can be achieved by setting some quality standards by considering the purpose of the system. There are some common accepted metrics which can be used to assess the quality of the tools. External metrics for measuring attributes of six quality characteristics defined in ISO/IEC 9126-1:2001(E) have been proposed in the technical report of British Standards Institution. These quality characteristics include functionality, reliability, usability, efficiency, maintainability and portability metrics. Cingil et al. (2010) propose a list of questions to evaluate the quality of the BPM assessment tool by considering this report. Similar questionnaire has been applied to decision makers who were involved in the pilot study after the questions were modified to comply with the purpose and usage of SSES. Questions and responds of four decision makers are provided in Appendix D and E.

The questionnaire is intended to measure the quality of the tool in terms of different metrics. Question 1, 2, 3, 11 are to find out functionality quality of the tool. All users think that the tool is suitable to evaluate suppliers. According to security and integration availability concerns only one user disagrees to the capability of the tool. The functions and the tasks of the tool are also regarded as reasonable and acceptable for evaluating suppliers. Question 4 and 5 are to measure the portability metrics of the tool. Processes are found as flexible by the users in terms of reusability. They also think that the tool can be used to evaluate and select entities other than suppliers. This proves adaptability of the tool. Question 6, 7, 8, 9, and 10 are to see how usable the tool is. All users agree that purpose and usage ways of the components (input areas) of the tool are easy to understand. Except one user, who thinks that the time to learn how to use the tool is acceptable, other three users keeps neutral. Warning and error messages are also found directive and understandable. But since all users keep neutral and there is no positive respond in this point, those messages might be improved in some way. This situation is similar for the relevance of the user guide and actual functions of the tool. The only issue to which all users disagree is the usability of the system in terms of appearance. It is obviously seen that the look and feel of the tool need enhancements. Colors, contrasts and layouts should be reconsidered and redesigned. Question 12 and13 is intended to measure the reliability. All users agree that the tool is free of software failures, which means that its fault tolerance level is high and increases the reliability. Users keep neutral in the similarity of tasks performed during the operation between the actual and the reasonable of expected results. This shows that results of each operation should be compared and source of differences should be eliminated. Last two questions, 14 and 15 are used to find out the efficiency of the tool which is one of the key points we focus on. All users strongly agree that the tool reduces the time spent on assessment and comparison of different suppliers. This result reveals the fact that we succeeded in providing an effective tool for supplier selection which enables fast and efficient evaluations. Similar to this question, the users also agree that the availability of changing evaluation criteria dynamically by users brings extra flexibility to the tool. This is one of the targets we aimed to achieve as well.

CHAPTER 7:

CONCLUSION

Supplier selection is one of the vital processes of organizations which affect many activities from inventory management to production planning and control and even cash flows and quality assurance. Supplier selection is a complex multi criteria decision problem in which the involvement of different parties is required. In order to achieve competitive advantage it is important for firms to spend the minimum time and effort to find the best, or most appropriate, supplier

Most complex decisions are made by groups in organizations. Group support in decision making is a critical aspect of this century's DSS's. The increase in organizational decision making complexity increases the need for group work. Supporting group work by bringing team members, who work at different times from different locations together, requires the effective use of communications, information and computer technologies. This study is placed at the intersection of GDSS's, computer (web) technologies and supplier selection process as the problem that is aimed to provide solution.

In this study, supplier selection processes of firms from various industries have been investigated to provide input for the design of a GDSS. SSES provides a dynamic and flexible group decision support platform that can be benefited by decision makers which can be used in organizations operating in different industries. In order to test the effectiveness of the system a pilot study has been conducted where decision makers from different backgrounds participate in order to evaluate potential suppliers and select best performing ones. Its ability to comply with the needs of effective supplier selection process and potential benefits to organizations is figured out.

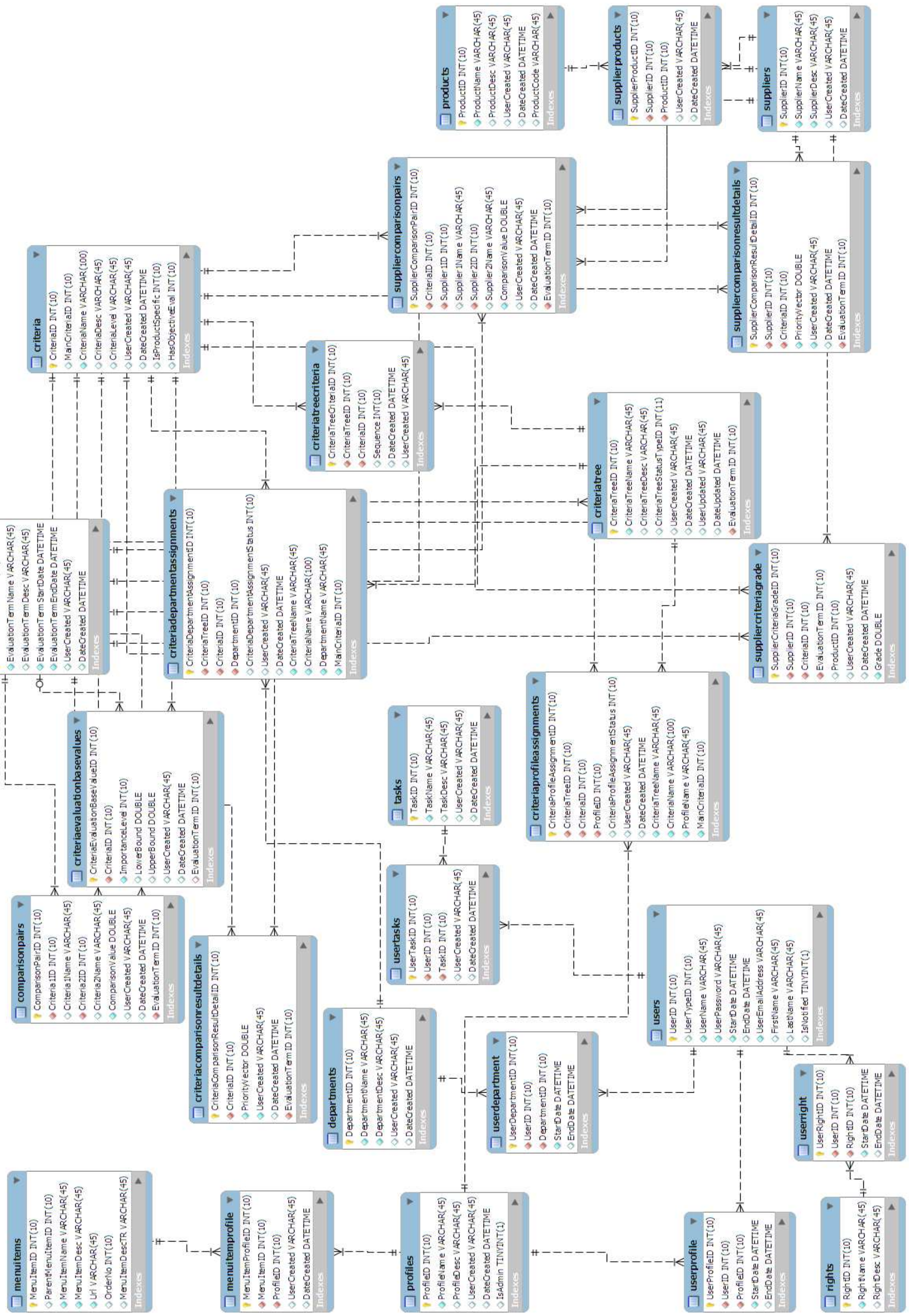
The results of the questionnaire, which is composed of questions to measure the ISO/IEC 9126-1:2001(E) quality compliance metrics of the tool show that the tool is robust and flexible enough to be benefit from in supplier evaluation. Although there are some look and feel concerns to which more attention should be paid, it provides a dynamic environment to all decision makers who are involved in the process from the creation to comparison of selection criteria. Reports produced by the tool at the end of the evaluation process include detailed strengths and blind spots of suppliers for each criterion. Reports also provide a reasonable weighted ranking of suppliers. Both suppliers and evaluator companies can take advantage of these features to build their own roadmap and performance improvement plans.

In the pilot study conducted to test the usability of the tool, a number of feedbacks have been collected. Decision makers think that in order to reflect their own preferences on some of the criteria, many inputs (comparisons) shall be provided to the system which is actually one of the drawbacks of AHP. In this situation the decision makers tend to select the same comparison values in order to reduce the consistency ratio which results in huge differences between alternatives (suppliers). To eliminate this, decisions makers should be trained well, especially the correlation between number of comparisons and the number of levels and/or criteria in the tree. Number of criteria in the tree shall be as low as possible, but they shall be sufficient enough to evaluate suppliers as well.

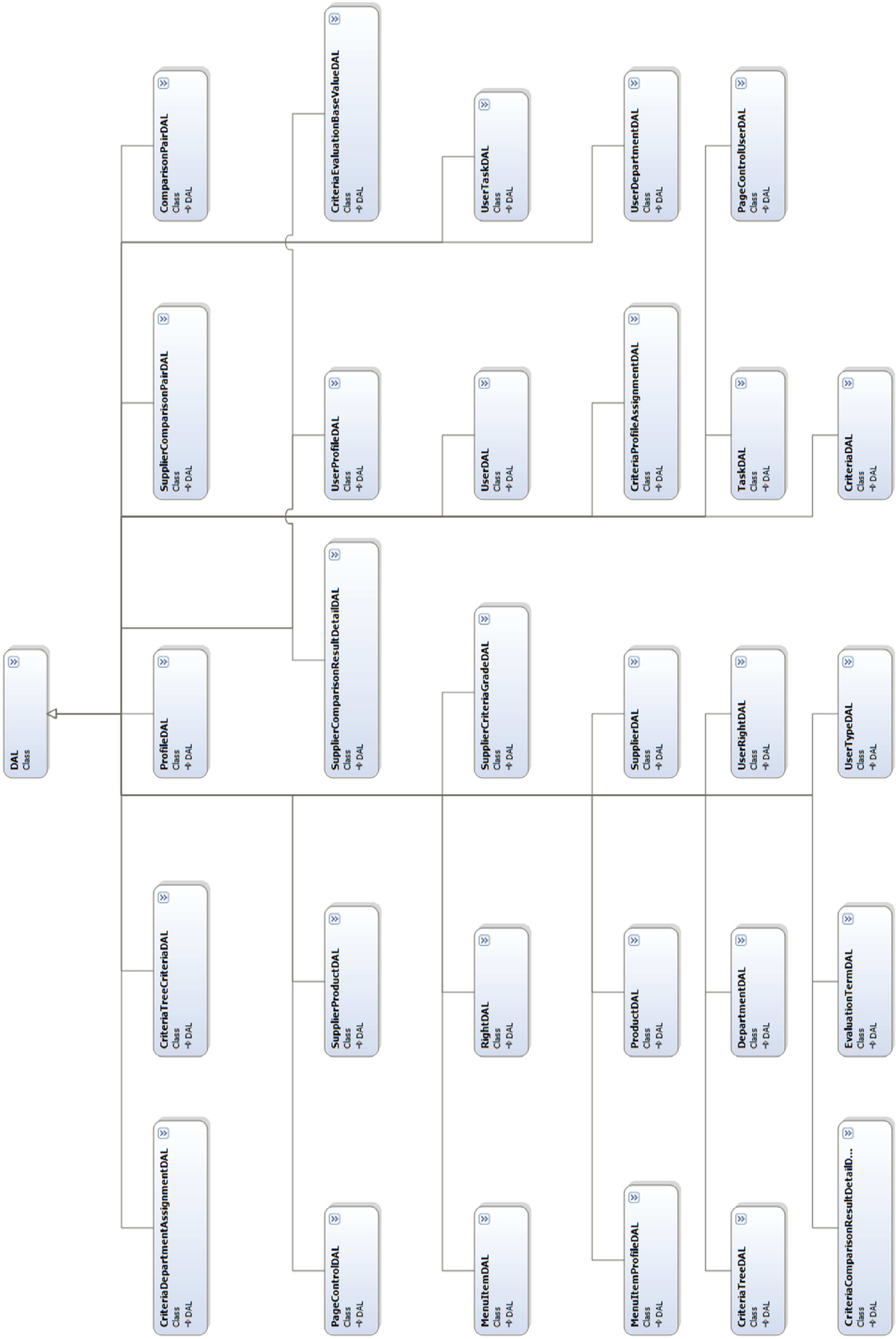
This study (tool) might be enhanced by seeking ways to integrate to other supplier selection tools and to implement some software utilizing tools. Also look and feel of the tool could be improved by taking some human computer interaction concepts in to account. Finally, a pilot study in which a huge number of companies from various industries would participate could be conducted. By doing so, the ability of the tool to comply with different industries could be measured and compared.

APPENDICES

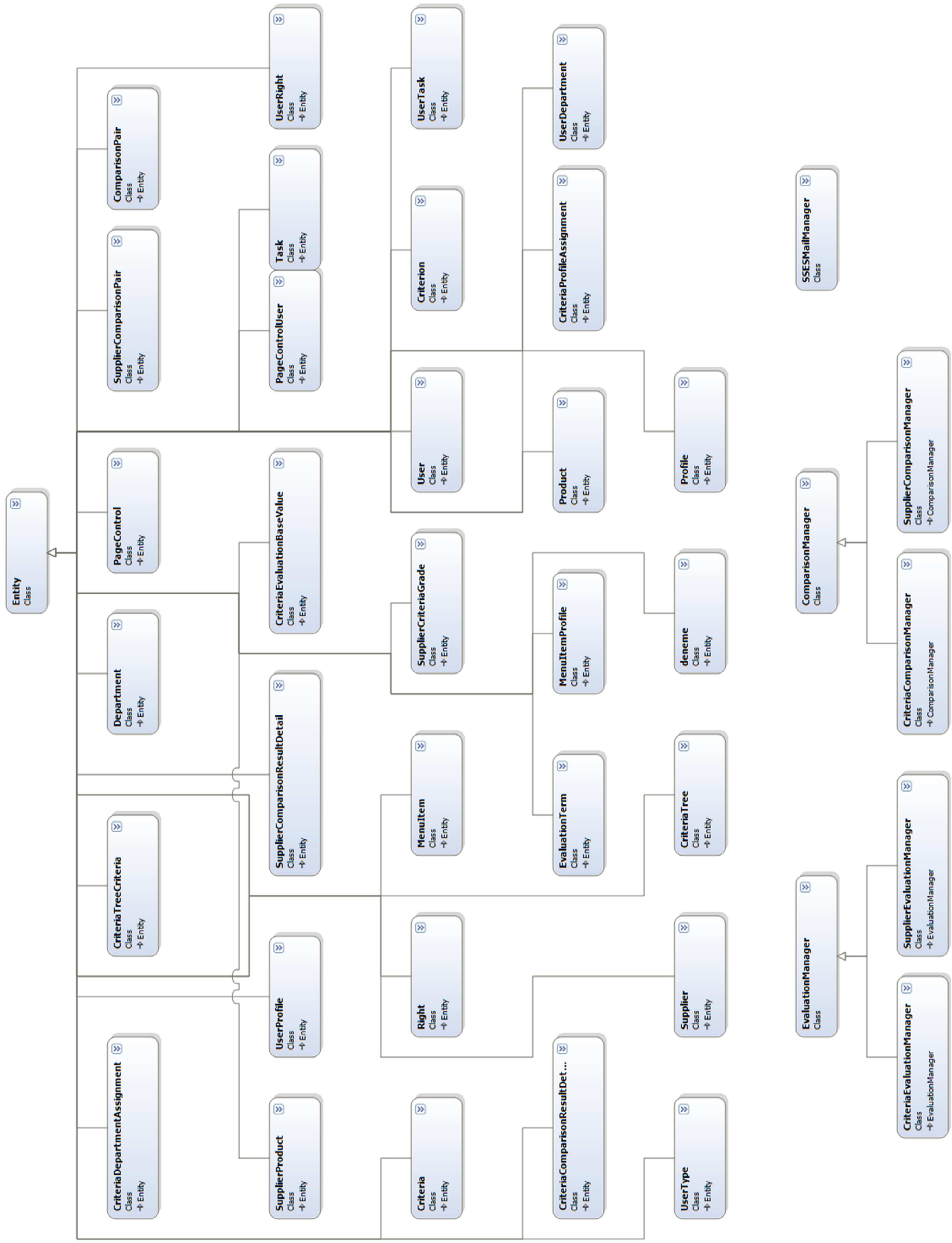
A. ENTITY RELATIONSHIP DIAGRAM (DATABASE SCHEMA)



B. DATA ACCESS LAYER CLASS DIAGRAM



C. BUSINESS LAYER CLASS DIAGRAM



D. EVALUATION QUESTIONNAIRE (TURKISH)

BOĞAZİÇİ UNIVERSITY

Yönetim Bilişim Sistemleri Bölümü

Bu anketin amacı “Tedarikçi değerlendirmesi için web tabanlı grup karar sistemi” kullanıcılarının sistem hakkındaki görüşlerini almaktır. Aşağıdaki sorulara vereceğiniz yanıtlar sistemin geliştirilirken göz önünde bulundurulacaktır. Yardımlarınız için teşekkür ederiz.

		1 Kesinlikle Katılmıyorum	2 Katılmıyorum	3 Kararsızım	4 Katılıyorum	5 Kesinlikle Katılıyorum
1	Sistem genel olarak tedarikçilerin değerlendirilmesi için uygundur.				4	
2	Sistem kullanıcı bilgilerinin ve kullanıcının girdiği verilerin güvenliğini sağlar. Sisteme girişte etkin bir kimlik doğrulaması yapılmaktadır.			3	1	
3	Sistem tedarikçi değerlendirme sürecinde kullanılan diğer sistemlere kolaylıkla entegre olabilir.		1	2	1	
4	Sistem varsayılan ayarlara (kriter tanımı vb) dönerek değerlendirme süreçlerinin yeniden başlatılabilmesine (sıfırlanmasına) olanak sağlar.			2	2	
5	Sistem tedarikçi seçimi dışındaki farklı değerlendirme problemleri (proje seçimi vb) için uyarlanabilir ve kullanılabilir.			2	2	
6	Sistemdeki veri giriş alanlarının (metin kutuları, seçenek düğmeleri, seçme kutuları vb) amaçları ve kullanım şekilleri açık ve anlaşılırdır.				4	
7	Sistemi kullanmayı öğrenmek için gereken süre kabul edilebilir seviyededir.			3	1	
8	Sistemdeki hata ve uyarı mesajları anlaşılır ve doğru yönlendirici niteliktedir.			4		
9	Sistemin görselliği (ekran tasarımları, kullanılan renkler vb) kullanılabilirliğini arttırıyor.		4			
10	Sistemin fonksiyonları, ekranları ve yapılan işlemleri kullanım kılavuzunda belirtildiği (olması gerektiği) gibi çalışıyor.			4		
11	Sistemin sunduğu fonksiyonlar ve yapılan işlemler sonucunda ortaya çıkan veriler tedarikçileri değerlendirmek için mantıklı ve kabul edilebilir sonuçlardır.			2	2	
12	Sistemin üretmesi gereken sonuçlar ile gerçekte ürettiği sonuçlar benzerdir.			4		
13	Sistemde yazılım hataları yoktur.				4	
14	Sistem farklı tedarikçilerin değerlendirilmesinde ve karşılaştırılmasında harcanan zamanı düşürüyor.					4
15	Değerlendirme kriterlerinin dinamik ve kullanıcı bazlı olarak değiştirilebiliyor olması sistemin esnekliğini arttırıyor.			1	1	2

Yorumlarınız:

E. EVALUATION QUESTIONNAIRE (ENGLISH)

BOĞAZİÇİ UNIVERSITY

Management Information Systems

The purpose of this questionnaire is to have the opinions of users for the tool "Web-based group decision support system for supplier evaluation". Your responses for the below questions will be considered afterwards for the enhancement of the tool. Thanks in advance for your cooperation.

		1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1	The tool is suitable for evaluation of suppliers.				4	
2	Tool provides security for user information and user data. Effective authentication exists for login.			3	1	
3	Tool can easily be integrated to other tools used in supplier selection process		1	2	1	
4	Tool enables to restart evaluation processes by the use of default configurations (criteria definitions etc)			2	2	
5	The tool can be customized for a specific evaluation problem (such as evaluation & selection of projects etc.).			2	2	
6	Input areas of the tool (textboxes, radio buttons, checkboxes) are easy to understand in terms of purpose and usage				4	
7	The time to learn how to use the tool is acceptable.			3	1	
8	Warning and error messages of the tool are easy to understand and directive.			4		
9	Appearance of the system (screen layouts, colors etc) increases the usability of the tool		4			
10	Functions and tasks of the tool are the same as specified (expected) in user manuals.			4		
11	Functions provided by the tool and data produced by the tasks are reasonable and acceptable for evaluating suppliers.			2	2	
12	The actual and reasonable expected results of tasks performed during operation are similar.			4		
13	The tool is free of software failures.				4	
14	The tool reduces the time spent on assessment and comparison of different suppliers.					4
15	Changing evaluation criteria dynamically by users increases the flexibility of the tool			1	1	2

Comments:

F. SCALES FOR QUANTITATIVE CRITERIA

Price (TL)	Lower Bound	Upper Bound
Very Good	1	99
Good	100	199
Average	200	274
Bad	275	349
Very Bad	350	1000

Company Age (Year)	Lower Bound	Upper Bound
Very Good	8	30
Good	6	7
Average	4	5
Bad	3	4
Very Bad	1	2

Number of Personnel	Lower Bound	Upper Bound
Very Good	9	100
Good	7	8
Average	5	6
Bad	3	4
Very Bad	1	2

Warehouse capacity (meter square)	Lower Bound	Upper Bound
Very Good	301	1000
Good	201	300
Average	101	200
Bad	11	100
Very Bad	1	10

Defect Rate (%)	Lower Bound	Upper Bound
Very Good	1	3
Good	4	5
Average	6	7
Bad	8	9
Very Bad	10	100

Lead Time(Day)	Lower Bound	Upper Bound
Very Good	1	2
Good	3	4
Average	5	6
Bad	7	8
Very Bad	9	50

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